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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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VOL. CVII.—No. 2785.] *LONDON: FRIDAY, MAY 16, 1919.* [*Registered at the General Post Office as a Newspaper.*] PRICE 9d. BY IRELAND POST ... 11d.

Aveling & Porter, Ltd.,
ROCHESTER, KENT,
and 72, CANNON STREET, LONDON.
STEAM ROLLERS. ROAD LOCOMOTIVES.
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STEAM WAGONS. TRACTORS.
CEMENT-MAKING MACHINERY. 7667

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ON ADMIRALTY AND WAR OFFICE LISTS.
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See Advertisement, page 38, last week.
PATENT WATER-TUBE BOILERS,
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2179

John H. Wilson & Co., Ltd.
Birkenhead.
See Illustrated Advertisement
Page 127.

Locomotive Shunting Cranes
Steam and Electric Cranes,
EXCAVATORS, CRANE-NAVVIES, GRABS, CONCRETE-MIXERS,
SHIPS WINDLASSES, WINCHES, and DECK MACHINERY.
6770
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Always British Large Sizes.
BLACKSTOCK BALL BEARING CO.,
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For Illustrated Advert., see page 6, April 11. 7356

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Manufactured by 2891
PETTERS LIMITED, Engineers, Yeovil.
See our illustrated Advt. every alternate week.

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TOOL MAKERS, JOHNSTONE, near Glasgow.
For class of Machine Tools see our Illustrated Advertisement every alternate week. 1358

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S. H. HEYWOOD & CO., LTD., 7182
REDDISH.

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COVENTRY. 610

Bever, Dorling & Co., Ltd.,
BRADFORD.
HIGH-CLASS ENGINES FOR ALL PURPOSES.
Also WINDING, HAULING, AIR COMPRESSING and PUMPING ENGINES. 1896

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of all types and sizes.
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Motherwell, near Glasgow. 7264

Telegrams—"Cylinders," Birmingham.
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TUBES LIMITED, BIRMINGHAM. 8179

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SHIPBUILDERS AND ENGINEERS,
GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF EXCEPTIONAL SHALLOW DRAUGHT.
Repairs on Pacific Coast
by YARROWS, LIMITED, Victoria, British Columbia. 6876
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

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SPECIALISTS IN
Drillers & Boring Machinery
for Engine Works and Boiler Shops.
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Yachts, Launches or Barges
Built complete with Steam, Oil or Petrol Motors; or Machinery supplied. Od 3551
VOSPER & CO., LTD., BROAD STREET, PORTSMOUTH.

Cochran MULTITUBULAR AND CROSS-TUBE TYPES.
Boilers.
See page 17, May 9. 7363

Electric Cranes.
7182
S. H. HEYWOOD & CO., LTD.,
REDDISH.

FOR
Drop Forgings
write
GARTSHERRIE ENGINEERING & FORGE CO.,
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Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO., LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 7360

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RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 7612

Excavators.
FROM 50 TO 600 YARDS PER HOUR.
D. Whitaker,
5315
1, UNION STREET,
LEICESTER.

AERIAL ROPEWAYS, CABLEWAYS, CRANES.
Steel Castings.
See displayed advertisement every alternate week.
JOHN M. HENDERSON & CO., ABERDEEN.

"Spencer-Hopwood" Patent Boilers.
Sole Makers:
W. H. SPENCER & CO., HITCHIN, HERTS.
See page 15, May 9. 7454

Henry Wells Oil Co.,
11, HAYMARKET,
London, S.W. 1.

"Aptol" Lubricants.
WORKS: SALFORD, MANCHESTER. 7184

Iron and Steel
Tubes and Fittings.
6920
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 103.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS,
CALORIFIERS, EVAPORATORS, } Row's Patents.
CONDENSERS, AIR HEATERS,
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 6736

Tubes and Fittings,
IRON AND STEEL.
Stewarts and Lloyd's, Ltd.,
41, OSWALD ST., GLASGOW.
BROAD STREET CHAMBERS, BIRMINGHAM; and LONDON OFFICE—
WINCHESTER HOUSE, OLD BROAD STREET, E.C.
LONDON WAREHOUSE—167, UPR. THAMES ST., E.C.
LIVERPOOL WAREHOUSE—63, PARADISE ST.
MANCHESTER WAREHOUSE—34, DEANSGATE.
CARDIFF WAREHOUSE—122, BUTE ST.
BIRMINGHAM WAREHOUSES—NILE STREET, SHEEPSCOTE STREET, and 10, COLESHILL STREET.
See Advertisement page 28. 7368

Die Finished Castings ensure rapid production and reduce prime cost by eliminating machining operations. Write for illustrations to AERATORS LTD., Edmonton, London, N. 18.

FLEXIBLE, NON-RUSTING
Metallic Hose-Covering to protect & strengthen tubing for all pressures and purposes. As supplied for H.M. Govt.—AERATORS LTD., Edmonton, London, N. 18.

R. Heber, Radford, Son & Squire,
ENGINEERING, IRON AND STEEL WORKS
Valuers.
CONSULTING ENGINEERS, REFEREES, AND ARBITRATORS.
Established over 50 years. 7108
15, ST. JAMES ROW, SHEFFIELD.
Telegrams: "Radford, Sheffield." Telephone: 495.

Locomotive Traversers
(ELECTRIC).
7182
S. H. HEYWOOD & CO., LTD.,
REDDISH.

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Duckham's Patent Suspended
WEIGHING MACHINES.—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes, Grain Elevators, &c.
See Illus. Advt. last week, page 15. 7046

Patent
See's Hydro-Pneumatic Ash Ejector.
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4835

Separators
— FOR —
EXHAUST STEAM TURBINES COMPRESSED AIR, &c.
STEAM DRYERS,
METALLIC PACKINGS.
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CHANTIERS & ATHLIERS
Augustin-Normand
97, rue de Perrey—LE HAVRE
(France). 3980
Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

Yarrow Patent
Water-Tube Boilers. 6084
MESSRS. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

John Bellamy Limited,
MILLWALL, LONDON, E.
GENERAL CONSTRUCTIONAL ENGINEERS, 1316
Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.
RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3383

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 55, May 9. 2403

Matthew Paul & Co., Ltd.
Dumbarton. 6899
LEVENFORD WORKS,
See Full Page Advt., page 82, May 2.

Taylor & Challen
Presses. 8196
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM
See Full Page Advertisement, May 2.

Steel Castings.
THOMAS SUMMERSON & SONS, LTD.,
DARLINGTON. 6974

Electric Transporters.
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REDDISH.

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CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS
OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 120, Trongate, GLASGOW. Od 3547
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Aluminium

INGOTS	for	JIGS & PULLEYS,
SHEETS	for	CHEMICAL VESSELS,
WIRE	for	ELECTRIC CABLES,
SECTIONS	for	MOTOR BODYWORK,
TUBE	for	TYRE MANDRELS,
POWDER	for	PAINT, &c., &c.

7369
DESCRIPTIVE LEAFLETS
free from
THE BRITISH ALUMINIUM CO., LTD.,
109, Queen Victoria St., London, E.C. 4.

B. & S. Massey, Ltd.,
MANCHESTER.
Steam Hammers,
Power Hammers,
Drop Stamps,
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QUICK DELIVERY. LARGE STOCK.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, Mount Street, Manchester.
Chief Engineer: C. E. Stromeyer, M.I.C.E.
Founded 1854 by Sir William Fairbairn.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 7479

Northampton Polytechnic INSTITUTE,

St. John Street, Clerkenwell, E.C. 1.
Principal: R. MULLINEUX WALMSLEY, B.Sc.
A SPECIAL SUMMER COURSE of Practical Instruction, extending over nine weeks, will be given in Oxy-Acetylene Welding on Monday, Wednesday and Friday evenings from 7.0 to 9.30, commencing on the 26th inst.
Fee for the course £1 10s. U 733

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

Establishment of City Office

for SALE of Surplus Government Property.

NOTICE TO EXPORT HOUSES.

In order to interest Export Houses in the Sale abroad of Surplus Government Property, and to deal readily and on the spot with enquiries from such firms, a branch of the Surplus Government Property Disposal Board has been set up in the City under the direction of Sir SYDNEY HENN, K.B.E.
The address of this office is HOLLAND HOUSE, 33, BURY STREET, LONDON, E.C. (Telephone No. Avenue 8058.) U 767

Industrial Administration.

Mr. EDWARD T. ELBOURNE,
AUTHOR OF
FACTORY ADMINISTRATION & ACCOUNTS,
will give, during June and July, at Winchester House, Old Broad Street, E.C., THREE COURSES of EIGHT LECTURES each in the following subjects:—
A.—FACTORY ORGANIZATION.
Wednesdays, 6 p.m. Commencing June 4.
B.—LABOUR ADMINISTRATION.
Thursdays, 6 p.m. Commencing June 5.
C.—FACTORY COSTING.
Fridays, 6 p.m. Commencing June 6.
Discussion will follow each Lecture.
Fee.—One Guinea for each Course.
Syllabus, on application by post, to—
Messrs. BRINDLEY & ELBOURNE,
Consulting Engineers,
110, Victoria Street,
Westminster, S.W. 1.
U 709

Inst. C.E., I. Mech. E., B.Sc.,

and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 7670

Inst. C.E., Inst. Mech. E.,

and all Engineering Exams. Correspondence coaching by practical engineers. I.C.E. successes 365 out of 393. Two Bayliss Prizes, "Proxime Accessit." Special features for foreign candidates. Write for booklet, &c.—Address, 7434, Offices of Engineering.

A.M.I.C.E. and A.M.I.M.E.

Tuition. Also Postal Courses in Mechanical Engineering, Aircraft Design and Mathematics.—PENNINGTONS, 354, Oxford Road, Manchester.

Correspondence Tuition

Courses for B.Sc., Inst.C.E., Inst Mech.E., and all Technical Examinations conducted by Honours (Engineering) University Graduate and fully qualified Engineer. Fees moderate.—Address, 7676, Offices of Engineering.

TENDERS.

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

GRAIN HANDLING APPARATUS AT THE GRAIN STORES, SWANSEA, comprising the following,

For Sale By Tender:—

Four Hopper Weigher Trucks containing two Weighing Machines complete with housing, doors, etc.
Two Hopper Weigher Trucks, each containing three Weighing Machines complete with housing, doors, etc.
33 Portable Horizontal Conveyors, 30 ft. long, provided with bulk grain feeding and discharging hoppers and guides for bag conveying.
Four Hoppers for sharp corners when conveying bags on conveyors.
Four Bulk Pilers.
Four Bag Pilers.
One Excavator.
One Portable Automatic Weighing Machine.
(Sets of spares for the whole of the above apparatus.)
Four Single-chain "Priestman" Grabs.
For further particulars, application should be made to the CHIEF ENGINEER, Engineering Division, H.M. Office of Works.
The whole of the plant will be on view from the 15th to the 29th instant and tenders will be received by the Office of Works not later than the 5th June. U 754

G. R.

BY ORDER OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

TWO SINGLE-LIFT GASHOLDERS & TANKS AT R.N. AIR STATION, KINGSNORTH.

For Sale by Public Tender.

TWO Single-Lift Spiral Guided GASHOLDERS—
40 ft. 0 in. diam. × 16 ft. 9 in. deep.
TWO Steel TANKS—
41 ft. 6 in. diam. × 17 ft. 0 in. deep.
All Tenders must be submitted by the 21st May, 1919.
Tender Forms and permits to view can be obtained on application to the CONTROLLER, Machinery and Plant (Demobilization), Charing Cross Buildings, London, W.C. 2. U 596

G. R.

BY DIRECTION OF THE DISPOSAL BOARD MINISTRY OF MUNITIONS.

PEARL BARLEY MILL MACHINERY & PLANT LYING AT COVENT GARDEN, FOR SALE BY TENDER.

Tenders are Invited for

MACHINERY and PLANT in connection with the Pearl Barley Mill, 150, Floral Street, Covent Garden, W.C. 2, including Milling Machines, Elevators, Power Friction Hoist, Dust Collectors, Combined Machine for dressing barley, Electric Motors, Shafting Pulleys, Roller Mills and Spares, etc.
Date of closing Tenders 2nd June.
Further particulars can be obtained together with permits to view and Tender Forms, from the CONTROLLER, Machinery and Plant, Charing Cross Embankment Buildings, S.W. 1. Telephone Gerrard 540. U 839

G. R.

BY DIRECTION OF THE DISPOSAL BOARD. MINISTRY OF MUNITIONS.

FOUR 50 HP. VERTICAL CRUDE OIL ENGINES, LYING AT YEOVIL, FOR SALE BY TENDER.

Tenders are Invited for Four

50 HP. Vertical two-cycle Crude Oil Engines, with 42 in. Pulleys together with four Self-starters, and four sets Cooling Tanks.
Made by Messrs. Petters, Ltd., Yeovil.
These Engines are lying at the Makers' Works.
Date of closing tenders June 9th.
For further particulars, Tender Forms and permits to view, apply to the CONTROLLER, Machinery and Plant, Charing Cross Embankment Buildings, S.W. 1. Telephone Gerrard 540. U 841

STEAM BOILERS AND PUMPS FOR SALE.

Tenders are Invited for any

part, or the whole of the following PLANT and MACHINERY, as they now lie, at the WYLAM PUMPING STATION of THE NEWCASTLE AND GATESHEAD WATER COMPANY.

Lot 1. One LANCASHIRE STEAM BOILER, 28 ft. × 7 ft. 6 in. dia., with Mountings as thereon, including Dampers, Flue and Sludge Cock Plates.
Lot 2. One Ditto Ditto.
Lot 3. One Ditto Ditto.
Lot 4. One Ditto Ditto.
Lot 5. One Ditto Ditto.
All the above Boilers were built by Messrs. Hawksley, Wild & Co., of Sheffield, under special supervision. They have done very little work, and are in excellent condition. Boiler reports can be inspected.
Lot 6. One LANCASHIRE STEAM BOILER, 28 ft. × 7 ft. dia., with Mountings as thereon.
Lot 7. One CAMERON DOUBLE RAM PUMP, Cylinders 8 in. × 8 in.
Lot 8. One TANGYE DUPLEX PUMPING ENGINE, cylinders, 9 in. × 12 in.
Tenders to purchase must be sent in sealed envelope, marked "Tender for Plant at Wylam," and addressed to THE NEWCASTLE & GATESHEAD WATER COMPANY, Pilgrim Street, Newcastle-upon-Tyne.
Inspection Orders, Forms of Tender, and Conditions of Sale, or any further information that may be desired can be had on application to:—
T. S. INNES,
Prudential Buildings, Newcastle-upon-Tyne.
U 749

Sale by Private Tender.

COMPLETE ALTERNATING CURRENT GENERATING PLANT consisting of:—
One 535 H.P. and Two 500 HP. Carels Three Cylinder Diesel Oil Engines, with Reavell Compressors,
Direct coupled to
Two 218 Kw. and one 325 Kw. Dick, Kerr 2-phase, 2000 volt, 50 period Alternators, with Direct Coupled Exciters.
Complete Auxiliary Gear, consisting of Reavell 4-stage Compressor, driven by direct coupled 2000 volt, 2-phase, 100 HP. Induction Motor; Marble Switchboard, with mechanical remote control for three generator and two feeder panels, with the usual measuring and synchronising gear; Motor Driven, Water Circulating and Fuel Oil Pumps; Heenan & Froude Water Cooling Plant for 7000 gallons per hour, cooling water and fuel oil tanks, fuel oil storage tanks of 90 tons capacity, and a quantity of new and second-hand spare parts.
Also one 20 ton Engine Room Crane, 47 ft. span, with hand traverse and electric hoist; and one 15 ton ditto, hand traverse and hoist, 37 ft. 6 in. span.
The whole is in good running order, and adjusted to run on either tar or crude oil.
The Plant may be inspected by prospective purchasers by appointment.
Offers will be considered for the whole or part of above plant.
Address, U 805, Offices of Engineering.

NORTH EASTERN RAILWAY.
The Directors are prepared to receive

Tenders for the Supply of

STEELWORK for the renewal of nine bridges on the Darlington and Saltburn Railway. The work consists of about 204 tons of Rolled Steel Beams; also about 78½ tons Riveted Steel Trough Girders and about 2½ tons of Cast Ironwork. Plans may be seen and specifications, detailed quantities and form of tender obtained on personal application at the Office of Mr. C. F. BENGOUGH, the Company's Engineer, York, on and after Wednesday, May 14th, 1919. Sealed Tenders marked "Tender for the supply of Steelwork for the renewal of nine bridges on the Darlington and Saltburn Railway" should be sent to the Secretary at York not later than 9 a.m. on Saturday, May 24th, 1919. The Directors do not bind themselves to accept the lowest or any tender.
R. F. DUNNELL, Secretary.
York, 8th May, 1919. U 742

COUNTY BOROUGH OF OLDHAM.

TRAMWAYS DEPARTMENT.

The Tramways Committee are prepared to receive

Tenders for the Supply and

delivery of Twelve Double Deck Top Covered TRAMCARS, with or without vestibules, complete with Trucks (6 ft. wheel base). Also 12 Complete 40 HP. ELECTRICAL EQUIPMENTS for the above.
Tenders, sealed and endorsed "Tender for Car Bodies," or "Tender for Electrical Equipments," must be delivered to the undersigned at Wallshaw Depot, Oldham, not later than first post May 27th, 1919.
The Committee do not bind themselves to accept the lowest or any Tender.
W. CHAMBERLAIN,
General Manager and Engineer.
General Manager's Office,
Wallshaw Depot, Oldham.
May 12th, 1919. U 792

THE CROWN AGENTS FOR THE COLONIES, acting on behalf of the Government of Nigeria, invite

Offers for a Powerful

MODERN TWIN-SCREW STEEL TUG, about 145 b.p. 29 beam, not exceeding 14 ft. draught with full load, Main and Auxiliary Machinery of latest type to develop about 1400 I.HP., Two Single-ended Scotch Boilers, Steam Windlass, Steering Gear, &c., Electric Light.
Offers, for which no special form is necessary, should give full particulars, including all details of Main and Auxiliary Machinery, Boilers, I.HP. revolutions, speed, accommodation, and maximum draught with bunkers full, and full equipment, price, and where available for inspection.
THE CROWN AGENTS FOR THE COLONIES,
4, Millbank,
Westminster, London, S.W. 1. U 808

HACKNEY BOROUGH COUNCIL.

The BATHS COMMITTEE of the Hackney Borough Council are prepared to receive

Quotations for any or all of

the undermentioned PLANT, which is now fixed at the Public Baths, Lower Clapton Road.
Davey Paxman & Co., Ltd., TWIN CYLINDER STEAM ENGINE, 25 HP. (horizontal) capable of developing 50 brake HP. at 60 lb. steam working pressure, complete with automatic cut-off and expansion gear.
Robey & Co., Ltd., VERTICAL HIGH-SPEED STEAM ENGINE, Indicated HP. 40, revs. per minute 300, steam working pressure 60 lb., governed by a Pickering sensitive high-speed governor.
Tangye & Co., Ltd., 12 HP. HORIZONTAL STEAM ENGINE, revs. per minute 76 at 60 lb. working steam pressure. Fitted with Tangye and Johnson patent cut-off gear.
AUTO CONVERTER, by Crompton & Co., Ltd., C.M.R. patent, K.W. 5, volts input 480, output 100 revs. per minute 1,000. With D.P. switch and starter.
10 in. Double Leather ENDLESS BELT, copper sewn, length 40 ft. 6 in., nearly new, orange tanned.
8 in. Double Leather ENDLESS BELT, length 27 ft. 6 in., good condition.
The Engines described above can be inspected and seen running if required by appointment with the Engineer on the premises; the buyers take all responsibility for accuracy of description, taking down and removal, and making good any damage which may be occasioned by such operations.
The plant will be disposed of as a whole or in separate lots, and the Committee reserve to themselves the right not to accept the highest or any tender. Quotations to be delivered to the undersigned, endorsed "Plant at Baths," not later than One p.m. on Thursday, the 5th June, 1919.
Town Hall, NORMAN SCORGIE,
Hackney, E. 8. Acting Town Clerk.
13th May, 1919. U 814

G. R.

BY DIRECTION OF THE DISPOSAL BOARD MINISTRY OF MUNITIONS.

ELECTRIC LIFTS LYING AT CHELSEA FOR SALE BY TENDER.

Tenders are Invited for the

undermentioned Five direct-coupled ELECTRIC LIFTS lying at 2nd London General Hospital Chelsea.
Three Direct coupled push button controlled Electric Passenger Lifts.
Two Direct coupled cage controlled Electric Bed Lifts.
Date of closing Tenders, 2nd June.
Further particulars can be obtained from the CONTROLLER Machinery and Plant, Charing Cross Embankment Buildings, S.W. 1. Telephone Gerrard 540. U 850

DUBLIN CORPORATION.
WATERWORKS COMMITTEE.
NEW RESERVOIR, ROUNDWOOD.

Notice is Hereby Given, that

the TIME for TENDERING for the completion of the above work has been EXTENDED, and tenders will be received up to Eleven o'clock a.m., on Tuesday, 27th May, 1919.
By Order,
CHARLES POWER,
City Hall, Dublin, Secretary.
13th May, 1919. U 852

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

SAUSAGE MANUFACTURERS' PLANT LYING AT POPLAR.

FOR SALE BY TENDER.

Tenders are Invited for

SAUSAGE MANUFACTURING MACHINERY AND PLANT, lying at Sausage Factory, Poplar, including Boilers, Motors, Sausage Filling Machines, Radiators, Steam and Water Piping, &c.
Tenders to close by 2nd June.
Further particulars with permits to view, and Tender Forms can be obtained from the CONTROLLER, Machinery and Plant, Charing Cross Embankment Buildings, S.W. 1.
Telephone: Gerrard 540. U 849

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

GASWORKS PLANT AT BOLTON, FOR SALE BY TENDER.

Tenders are Invited for the

following GASWORKS PLANT, lying at Lum Street Gasworks, Bolton:—
One Second-hand Boiler, 24 ft. by 6 ft. 6 in. dia., working pressure 50 lbs. per square inch, complete with feed water supply, etc.
Also Boiler Shell, 20 ft. by 7 ft. 6 in., Separators, Pumps, Steam Trap, C.I. & W.I. Mains, C.I. Pipes, Pipe Fittings, Valves, Cocks, etc.
Full particulars, Tender Forms, and Permits to view may be obtained from the CONTROLLER, Machinery and Plant Disposal Board, Charing Cross Embankment Buildings, S.W. 1. Telephone: Gerrard 540.
All Tenders should reach the Controller by Ten a.m. on 2nd June, 1919. U 768

APPOINTMENTS OPEN.

CITY OF BIRMINGHAM EDUCATION COMMITTEE.

Lecturer in Engineering

(full time) REQUIRED for Day and Evening Classes at Handsworth Technical School. Commencing Salary from £250 to £300 per annum according to qualifications and experience. Full particulars and forms of application can be obtained from the PRINCIPAL,
JNO. A. PALMER,
Secretary for Education. U 813

HALIFAX EDUCATION COMMITTEE.

MUNICIPAL TECHNICAL COLLEGE.
Principal—J. Crowther, B.Sc. (Lond.).

Applications are Invited for

the following POSITIONS:—
1.—Head of the Mechanical and Electrical Engineering Department. Salary £350 per annum, rising by annual increments of £20 to £500 per annum.
2.—Assistant in the Electrical Engineering Department.
3.—Assistant in the Mechanical Engineering Department.
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AIR MILEAGE OF AEROPLANES INTENDED FOR LONG DISTANCES AND FOR TRANSPORT.

By J. DENNIS COALES, D.Sc., Captain R.A.F.

(*Concluded from page 594.*)

The Effect of Winds on the Air Mileage.—In long-distance flights the advantages or disadvantages of a wind according to whether it is a following wind or a head wind are very greatly accentuated. As already pointed out, if an aeroplane is designed to fly at a high speed, then either its aerodynamic efficiency is comparatively low, or its getting-off speed must be dangerously high. For example, if a machine is designed with a high loading, so that at its maximum $\eta \frac{L_e}{D_e}$ it flies at 5,000 ft. with a speed of 100 m.p.h., then Fig. 9 (page 593 *ante*) shows that its getting-off speed will have to be between 80 and 90 m.p.h. There would not be much difficulty in landing such a machine after a long flight of, say, 2,000 miles, because its loading would have become so reduced by the consumption of fuel and oil, that its speed near the ground, with its lift coefficient near its maximum value would be very much less than the getting-off speed at the beginning of the flight. It is clear, then, that if high aerodynamic efficiency during flight and a moderate getting-off speed are the conditions, then the flight must be done at a moderate air-speed, and a head wind will have a much more serious effect in reducing the mileage than in the case of a high-speed machine of the same aerodynamic efficiency. But in a high-speed machine with a moderate getting-off speed the aerodynamic efficiency during flight will be low, and in consequence, although less mileage is wasted against the head wind, the air mileage of the machine is itself less than that of the lower-speed machine. It is therefore a question in any particular case as to which of the two sets of conditions will result in the greatest range being obtained.

Referring to equation (9), we find that—

$$x = -\int_1^q \frac{m}{q} \cdot dq$$

where x = air mileage traversed while the loading was reduced from its initial value to q times that value by the consumption of fuel, and m = the pound-miles per pound of petrol at any point x air-miles from the starting point.

Let V be the velocity of the wind, taken as positive when the wind is following, and U_A the air-speed of the aeroplane, both being expressed in miles per hour. Then it is clear that with flight along the wind direction the pound-miles per pound of petrol becomes $\frac{V+U_A}{V} \times m$, and the mileage is given by—

$$x = -\int_1^q \frac{V+U_A}{V} \times \frac{m}{q} \cdot dq$$

To obtain the mileage properly this integral must be evaluated graphically, because V is not constant. But, as shown in Fig. 6, page 560 *ante*, its variation is small, and for the purpose of considering the effect of winds it may be taken as constant, so that—

$$\text{Approximately } x = -\frac{V+U_A}{V}\int_1^q \frac{m}{q} \cdot dq \quad . \quad (23)$$

That is to say, the mileage is equal to the air mileage multiplied by

$$\frac{\text{ground speed}}{\text{air speed}} \text{ or by } \left(1 + \frac{\text{wind speed}}{\text{air speed}}\right).$$

By taking the mean air speed during the flight, as found from Fig. 6, the mileage can be estimated quite closely enough for all practical purposes.

We are now in a position to see whether in a particular case, when a machine has to fly against a head wind, it is better to arrange for the machine to fly at its maximum $\eta \frac{L_e}{D_e}$ and the comparatively low speed associated with this, or to fly at a high speed with a comparatively low $\eta \frac{L_e}{D_e}$.

An analysis of a trial of a certain aeroplane showed that when its speed was 128 m.p.h. at 5,000 ft. its $\eta \frac{L_e}{D_e}$ was equal to 4·25. Whereas, when it flew at 84 miles per hour its $\eta \frac{L_e}{D_e}$ was equal to 6·8.

Now, suppose that the machine was designed to carry a weight of petrol equal to 40 per cent. of its total initial weight, then Fig. 6 shows that in the first case its air mileage would be 1,500 and in the second 2,440. The mean air speeds in each case would be 0·978 of the initial values, viz., 125 and 82 m.p.h. respectively.

Against a head wind of 40 m.p.h. the mileages will then be $\left(1 - \frac{40}{82}\right) \times 2{,}440 = 1{,}250$ miles, and $\left(1 - \frac{40}{125}\right) \times 1{,}500 = 1{,}020$ miles.

In this case, therefore, the advantage lies with condition in which the machine is given just enough engine power to enable it to fly at full throttle at its attitude of maximum $\eta \frac{L_e}{D_e}$, and at the lower initial speed of 84 m.p.h.

It is interesting to take the case of a machine with a much smaller top speed. The analysis of this machine, a large twin-engined bomber, gave the following figures :—

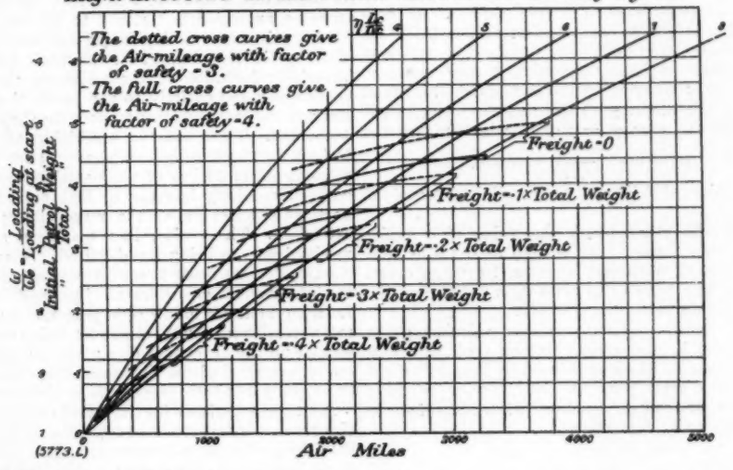
Speed at 5,000 Ft.	Aerodynamic Efficiency.
74·4 m.p.h.	6·3 (max).
89·5 m.p.h.	5·2

Suppose that provision is made, as before, that the machine shall have an initial weight of petrol equal to 40 per cent. of the total weight. Then the maximum air mileages are—

with $\eta \frac{L_e}{D_e} = 6{\cdot}3$ air mileage = 2,200 miles.

with $\eta \frac{L_e}{D_e} = 5{\cdot}2$ air mileage = 1,840 miles.

Fig. 11. AIR MILEAGE OF AEROPLANES.
With Level Flight at constant $\eta \frac{L_e}{D_e}$ starting at 5000' and with 0·5 Lb. of petrol per Standard B.H.P. Hour. Height-Horse Power correction factor taken as for stationary engines.


The dotted cross curves give the Air-mileage with factor of safety = 3.
The full cross curves give the Air-mileage with factor of safety = 4.
Freight = 0
Freight = 1 × Total Weight
Freight = 2 × Total Weight
Freight = 3 × Total Weight
Freight = 4 × Total Weight
W/W0 = Loading / Loading at start = Initial Petrol Weight / Total
Air Miles
(5773.L)

The mean speed during the flight is in each case 0·978 of the initial value, *i.e.*, 72·8 and 87·5 m.p.h. respectively. With a head wind of 30 m.p.h. the mileages are therefore with

6·3	...	...	...	...	...	1,300 miles.
5·2	...	...	...	...	...	1,210 miles.

In this case also, therefore, it is better to aim at flying with the higher aerodynamic efficiency than with the higher air speed. The reduction of mileage in both these examples shows how very serious an obstacle a head wind is to the crossing the Atlantic, and it seems improbable that a regular cross-Atlantic non-stop service will ever be established, without very radical improvements being made in the methods of design of aeroplanes.

A little consideration will show that, as far as range is concerned, it requires a very big head wind to render flying at top speed the better proposition.

The advantages of a following wind are, of course, obvious.

The amount of petrol necessary for the flight is reduced as well as the duration of the flight, which in the case of a head wind is increased, the reduction or increase in the duration being roughly proportional to the wind speed.

The effect of a cross wind in reducing the mileage is, of course, less than that of a head wind of the same speed, but with the added disadvantage of causing a drift, which cannot be observed during flight, and which can, therefore, only be corrected approximately by means of preliminary estimates based on weather reports; unless and until directional wireless signals are resorted to.

Before concluding this paper it is interesting to calculate the air mileages that it would be possible to attain with various proportions of load to total weight, when the minimum factors of weight economy as given in Table IV form the basis of the calculation. The speed of the aeroplane will be taken as 76 m.p.h. at 5,000 ft., giving the following values of λ the pounds of total weight carried per standard brake horse-power :—

$\eta \frac{L_e}{D_e}$	λ
5	20·8
6	25·
7	29·2
8	33·3

Taking equation (14) and substituting the minimum values from Table III, we find the following relations between the proportions of load and petrol to total weight, when the factor of safety of the machine is 4 :—

$$\eta \frac{L_e}{D_e} = 5 \quad l + 1{\cdot}216\, r = 0{\cdot}477$$
$$,, \quad = 6 \quad l + 1{\cdot}216\, r = 0{\cdot}505$$
$$,, \quad = 7 \quad l + 1{\cdot}216\, r = 0{\cdot}524$$
$$,, \quad = 8 \quad l + 1{\cdot}216\, r = 0{\cdot}539$$

With the weight of machine all up increased so that the factor of safety is reduced to 3, we have a new set of relations, calculated by means of equation (22).

$$\eta \frac{L_e}{D_e} = 5 \quad l + 1{\cdot}216\, r = 0{\cdot}533$$
$$,, \quad = 6 \quad l + 1{\cdot}216\, r = 0{\cdot}564$$
$$,, \quad = 7 \quad l + 1{\cdot}216\, r = 0{\cdot}586$$
$$,, \quad = 8 \quad l + 1{\cdot}216\, r = 0{\cdot}6025$$

By substituting values of l in these equations, r is calculated, and by means of Fig. 6 the air mileage is found, corresponding to a specific petrol consumption of 0·5 lb. per standard brake horse-power. If the specific consumption has any other value the new range is easily found by inverse proportion, for the air mileage is inversely proportional to the specific consumption. Tables V and VI have been calculated in this way.

TABLE V.—*Maximum Air Mileage of an Aeroplane with the best Weight Economy Factors of Table IV., and with a Factor of Safety 4, for various Proportions of Freight.*

Freight ratio =	0·0	0·1	0·2	0·3	0·4
$\eta \frac{L_e}{D_e} = 5$	1,720	1,310	930	570	250
,, = 6	2,200	1,700	1,250	800	410
,, = 7	2,710	2,100	1,530	1,010	550
,, = 8	3,220	2,510	1,840	1,230	710

The air mileages of Tables V and VI have been plotted together with the freight ratios in Fig. 11, which comprises a partial reproduction of Fig. 6.

When the aerodynamic efficiency $\eta \frac{L_e}{D_e}$, the factor of safety (within limits) and the freight ratio of a machine are known, the diagram enables the ratio of petrol weight to total weight and the air mileage, that should be obtained, to be read off, provided that the machine has a weight economy as good as that expressed by the minimum values of Table IV. If the specific petrol consumption differs from 0·5 lb. per standard brake horse-power hour, then the air mileage must be corrected in inverse proportion to its value.

TABLE VI.—*Maximum Air Mileage under Conditions similar to those for Table III, but with Factor of Safety* 3.

Freight ratio =	0·0	0·1	0·2	0·3	0·4
$\eta \frac{L_e}{D_e}$ = 5	1,980	1,530	1,140	770	430
,, = 6	2,550	2,000	1,500	1,050	650
,, = 7	3,120	2,480	1,870	1,330	840
,, = 8	3,700	2,960	2,270	1,620	1,040

A still further increase in the above air mileages could be made, if the amount of oil carried were reduced to be only just sufficient to last out the petrol. But it can be shown that the gain in air mileage is not sufficient to warrant the risk attached to such rigid economy. In the appendix it is explained how the value of the factor f can be calculated with this economy in view, and if this is done for the individual cases represented in the second columns of Tables V and VI, it will be found that the air mileages can only be increased by from 5 to 6 per cent.

APPENDIX.

The Weight of Oil, Oil-Tanks and Petrol Tanks per Pound of Petrol.—In Table IV of the preceding paper a factor f is assigned certain values, which were found by weighing the tanks of the aeroplanes then being considered. These values were particular values, so it is now proposed to give a general expression, which will enable f to be predicted with reasonable accuracy from a knowledge of the relation between the weights of tanks and their contents, and the oil and petrol consumptions of the engines to be used.

Let O = the total weight of oil required for a flight.
P = the total weight of petrol required for a flight.
o = oil consumed per pound of petrol.
n_o = the number of oil tanks taken as of the same size.
n_p = the number of petrol tanks taken as of the same size.

An examination of curves connecting the weights of tanks and their contents, for tanks of the usual forms, shows that the weight of oil tanks may be expressed by

$$n_o a_o + b_o \mathrm{O}$$

and the weight of petrol tanks by

$$n_p a_p + b_p \mathrm{P}, \quad a_o, b_o, a_p, b_p \text{ being constants.}$$

The contents of each tank being on the average $\frac{\mathrm{O}}{n_o}$ and $\frac{\mathrm{P}}{n_p}$ respectively. Therefore, the weight of oil tanks per pound of oil is:

$$o_t = \frac{n_o a_o}{\mathrm{O}} + b_o$$

and the weight of petrol tanks per pound of petrol:

$$p_t = \frac{n_p a_p}{\mathrm{P}} + b_p.$$

Now since o is the oil consumed per pound of petrol, the weight of oil tanks required per pound of petrol is $o \times o_t$.

We, therefore, have for the weight of oil, oil tanks and petrol tanks per pound of petrol, denoted by f:

$$f = o + o \times o_t + p_t$$

and by substitution

$$= o + o\left(\frac{n_o a_o}{\mathrm{O}} + b_o\right) + \frac{n_p a_p}{\mathrm{P}} + b_p$$

re-writing this relation we get

$$f = \frac{n_o a_o + n_p a_p}{\mathrm{P}} + o(1 + b_o) + b_p.$$

The curves connecting the weights of ordinary steel tanks and their contents, containing between 500 and 1,500 lb. of petrol, and weights of oil which would be provided with these amounts of petrol show that approximately:

$$a_o = 8. \qquad a_p = 12.$$
$$b_o = 0.06. \qquad b_p = 0.07.$$

substituting these values:—

$$f = \frac{8 n_o + 12 n_p}{\mathrm{P}} + o \times 1.06 + 0.07.$$

In the case of very large tanks to hold up to 7,000 lb. of petrol the value of b_p falls to 0·057.

In large aeroplanes P is generally great enough to render the first term on the right hand side small compared with the other two, so that o which depends upon the rate of oil consumption becomes an important factor.

The value of o to be taken depends upon the mean height of flight. Its value, found from engine trials at standard air density, must be divided by the relative air density at the mean height of flight, because whilst the oil consumption of an engine is (so far as is known) not appreciably affected by air density, the petrol consumption, with altitude control, is directly proportional to relative density.

As an example of the value of f calculated by the above relation, let the number of oil and petrol tanks in a particular case be two each, and the total weight of petrol required be about 3,000 lb., then:

$$f = 0{\cdot}0133 + o \times 1{\cdot}06 + 0{\cdot}07.$$

The smallest value of o (the ratio of oil consumption to petrol consumption at normal brake horse-power) that has been obtained in trials of commercial stationary engines, under standard conditions of air temperature and pressure, is about 0·05. If the flight were done at the mean height of 13,000 ft., then $\rho = 0{\cdot}673$, which makes the value of o to be used $\frac{0{\cdot}05}{0{\cdot}673} = 0{\cdot}074$.

The value of f (if no surplus oil be allowed) is then 0·162.

If, on the other hand, the value of o under standard conditions were as high as 0·12, as it is in some good stationary engines, its value corresponding to a height of 13,000 ft. is 0·178, and the corresponding value of f is 0·272.

If this value of f were used in calculating the air mileage in the second columns of Tables V and VI, they would all be reduced by from 5 to 6 per cent., which gives some idea of the value of using engines with good oil economy when long-distance flights are to be undertaken.

TEMPLETS, JIGS AND FIXTURES. No. XXIV.

By JOSEPH HORNER.

IN concluding this series we propose to take a survey of, and summarise the principal controlling facts and aspects of this very many-sided subject. A fairly representative selection has been given of present-day practice, ranging from the simplest to the most complex designs.

We have to recognise the limitations of jig and fixture work. They are imposed chiefly by dimensions, shapes, or the numbers required. Though articles of increasingly larger dimensions are jigged, no examples occur of very massive pieces being treated in this way. The first objection is the great weight of metal that has to be put into the fixture or jig, the second, the relatively small numbers that are wanted. A single main frame or foundation element will have hundreds of subordinate pieces built into it, many of which will be included in assembled units, as gear boxes, reversing mechanisms, shaft mountings, and so on. The limits to dimensions generally to fixture work have been illustrated in some of the foregoing articles. Even for these the loaded fixtures have been too heavy to be handled without employing power appliances, or trucks.

In the case of the heaviest framings, too big to be lifted and moved readily in this way, excellent results can be secured either by templeting, or by lining-out, and gauging. A vast amount of this was formerly done, but which is now appropriated by the fixtures and jigs. Yet a considerable proportion remains, in which the old methods must needs be retained, as being the only ones that are really practicable. Some examples of this kind were illustrated in early articles, and these are typical of much that is still accomplished in similar classes of manufacture. Simple marking-off secures a close degree of accuracy in the hands of an experienced man. Marking-off done from a templet favours uniformity, lessens risk of slight errors, and prevents big mistakes. Turning a templet into a jig is done to deal with large articles. The jig is constructed lightly, but thick blocks are attached to it to guide drills and reamers. When several faces and holes are related the method is more reliable than that of marking-off alone.

An alternative method that has been adopted is to store a duplicate of each of the components that make up an engine, a crane, or a machine, and refer to these as checks on manufacture. This method enables corrections to be made in the shops when supplying spares or replacing worn parts, and avoids annoyance at the place of destination. It is not so satisfactory as the preservation of templets, jigs and fixtures, being neither so accurate nor economical. But it fills a useful place when the product is small, or for the purpose of permanent shop reference in a perfect scheme of jigging.

The system of jigs and fixtures, and the standardisation which is associated with, and is inseparable from them, has been marked by vast developments which are as potent as those that concern the design of the machine tools on which they are used. Its growing extension is testified to by the numbers of advertisements calling for jig and tool draughtsmen, specialists set apart for this work, and by the invariable inclusion in the advanced shops of a section devoted entirely to the production of jigs, fixtures and tools, whether made in the shop or in the tool-room. These aids to machining are characterised by increasing complexity and by high refinements of fitting, of work-setting, and of tool control, entailing increase in first cost, but proportionate lessening of the responsibility of the attendant. These also, like machines and unit mechanisms are being standardised. Screws, pins, clamps, &c., are made to set dimensions, and stored to interchange on different jigs and fixtures. Locating methods follow rigid patterns, some being more suitable for rough, others for finished surfaces, so that no time is occupied in making approximate settings, and all pieces thus located for tooling will fit precisely into their proper places when assembled.

Mental comparisons inevitably visualise when we observe how different firms adopt diverse methods of holding and toolingin fixtures and jigs. They differ much in their characteristics and in the economic results achieved. One marked contrast is that of the multiplication of these aids, *versus* the concentration of numerous operations on work held in one appliance, or in a very limited number. This difference is associated with the endeavour to utilise existing machine tools in one case, and in the other with the practice of making adaptations in designs of tools to suit the work, or the later and more bold determination to redesign and build machines strictly round the product—the "single-purpose" machines. Few comparatively are the firms who adopt the last method, but those who do so generally find their justification for the venture in increased business. Really this policy grows as naturally out of the jig and fixture schemes, as these have developed from the simple templets. The single-purpose machine becomes the predominant partner, or at least an element of equal potency with the fixture and jig.

The diversity observable in the forms of fixtures, and of the methods adopted for tooling articles that are of similar outlines is very largely the consequence of the conditions that are imposed by the character of the plant available—a result of the desire to utilise existing machines which admittedly may not be the best possible for mass production. This handicaps firms who do not command the capital necessary for the purchase of more adaptable, more suitable tools. Then the problems that call for solution receive diverse treatments which goes far to account for differences in designs. Much may be done on machines that are not the best possible for the work put upon them, by the scheming of appropriate fixtures and jigs. Thus it results that the practice of one shop is not like that of another, since local conditions and equipments impose

restrictions, and outside criticisms concerning better designs possible are not justified. And yet the choice of one method rather than of another is very often a matter of preference, opinion, predeliction, prejudice perhaps, as in ordinary machine work, and in these cases the expression of adverse opinion may be permitted.

But apart from these diverse solutions, many instances arise in which the selection of methods is nearly or absolutely self-determined. In the case of thin pieces to be tooled in large numbers, no machine can rival the vertical spindle grinder, equipped with a magnetic chuck. But when plane surfaces on substantial pieces of work, to be tooled with heavy cuts are concerned, the choice must lie between planing and milling. Again, to deal with pieces singly or in multiple must often change the aspect of the problem. Where practicable, articles should be mounted in lineal series—tandem, on long-stroke machines, which, if dealt with singly, would not be so treated, because of the short strokes and wasteful reversals involved. The fixture may well be equal in length to the whole stroke of the table. A wide table may be utilised to carry two such fixtures, or double rows of pieces in one wide fixture. But here the Lincoln milling machines and the plano-millers throw the planing machines into the shade. Planing involves many traverses to cover a surface, and rapid reciprocations, and big demands on power. The single-edged cutting tool is at a disadvantage with the multi-toothed milling cutter, which is hardly limited in size or shape, or in the varied combinations of gang arrangements to deal with several related faces, curves, and contours. The horizontal spindles carrying face cutters take charge of deep vertical faces, which on other machines would involve resetting. The length of stroke, and the slow traverse are most favourable to the continuous running of these machines, because one-half the table can be loading up, while the work on the other moiety is undergoing tooling. In the machines where this is not practicable, the cost of duplicate fixtures to be loaded away from the machine is a provision that may be economical. Even a moderate product will afford sufficient justification for the outlay, because the question involved is not alone the more rapid output, but also the time charge against the machine when it lies idly during reloading. The pillar and knee machines, and the small Lincoln millers show to much less advantage from this point of view, but they fill a useful place for small pieces treated singly, or in series. Many of these fixtures are of very plain designs and cheaply made, but the pieces can be attached more rapidly to them than to the tables directly. It is cheaper too than putting small pieces singly on the shaper, or other short-stroke machines. The fixture can be scrapped when it has served its purpose, or be stored if orders are likely to be repeated. When a casting must have holes drilled in it at many centres or various angles, the cost of a fixture jig is justified even for a small number of pieces. It is indispensable if interchangeability is to be guaranteed. Holes can be drilled at several angles with accuracy on standard machines by the aid of a fixture.

When the strictly normal functions of machine tools are made to do service in special duties, this, in perhaps the majority of instances where distinct kinds of operations are involved, entails the transference of the work between a succession of fixtures, with consequent resettings for the performance of operations of various kinds on different faces. Often the holding is accomplished by methods which are hardly to be classed among fixtures, as when single cylinders for motor cycles are held in special jaws on face plates, to be bored, turned, or faced. Or when cock bodies are held in chucks with provision for turning and locking at 90 deg. Vee-blocks variously modified, and many packings, belong to this simple class. To increase the number of pieces put into large fixtures entails the use of large machines, and increases the work of handling. In advanced shops the labour of changing the work between fixtures on adjacent machines is lessened by the employment of conveying systems. In this way batteries of Ingersoll milling machines have been arranged, each with its appropriate fixture, and the operators only have to lift the work, which is carried between the machines by roller gravity conveyors. The pieces are the upper and lower halves of crank-cases, which, though bulky, are light enough to be handled, being in aluminium. Each fixture holds 10 castings. There is no pause in the operations. Two men attend to each machine. Reloading is done during the return stroke of the table, but the clamping when the table moves forward for cutting. A six-spindle boring machine is included in the battery to deal with the holes for the cylinder seatings. The milling machines are the firm's standard designs, modified with a view to the character of the work regularly done in regard to speeds and feeds, and the cross rails are cast solidly with the housings.

A case of the adaptation of a common tool is that in which a slab milling machine was made to serve for cutting off shell blanks from bars. Seven saws mounted on the arbor, and spaced at the correct distances for the shell lengths, severed eight blanks simultaneously. The bars—32 in number—were carried on vees in the fixture, and held down with spring clamps gripping adjacent bars. The clamp plates alternating with the saws, the blanks do not shift when severed. The length of the table permits one-half the number of bars to be loading, while the others are being sawn. The net result is that 670 blanks are severed in 10 hours. Following the sawing they are finished with horizontal face-milling cutters, while secured in a long fixture which holds 85 blanks. This is a rectangular frame divided by ribs into pockets, in which the blanks are gripped with set screws. One moiety is being loaded while the pieces in the other are being milled. Eighty-five pieces are tooled in 1¼ hours.

Cylinder work occupies a larger place than ever in the machine shop, and is fruitful in alternative methods. To bore cylinders singly, does not represent the highest development in motor work. Multiple tooling is adopted on machines that carry as many spindles as there are bores. Associated with this work is that of the facing of ends of the various boss faces, and the drilling, reaming and tapping of stud holes. Continuous and multiple tooling are both brought into service. Multiple work in boring and drilling, continuous in milling. Formerly, when single cylinders were bored, the flanges were faced at the same setting, with a star feed. That is abandoned in automobile work, the boring and facing being done on separate machines. Flanges are generally faced on the plano-miller rather than on the planing machine. The usual designs have one or more vertical spindle heads on the cross-rail, and a horizontal spindle head on each flank. Then, having only one vertical head, three surfaces are being tooled at one time, and there may be from six to eight cylinders set up in series. But as two rows of castings can often be got on a wide table, and two vertical spindles fitted, four sets of faces can be undergoing tooling at one time. In one case an Ingersoll machine tools 10 four-bore cylinder castings on bottoms and sides simultaneously. And these are not machines designed specially for the work, but are of general utility.

Obviously this method of mounting many pieces in one fixture has its limitations. It is not applicable to articles that must needs be dealt with individually. The teeth of gear blanks can be roughed out several at a time, but they must be finished singly. Then batteries of standard machines provide for a big product. In one case, 10 Gleason gear shapers are occupied in roughing-out blanks for motor vehicles, and in a row adjacent 10 other machines take the finishing cuts. No transport is required in this case, since the gears are lifted readily. In a special fixture made for roughing-out with rotary cutters, six blanks are being dealt with at one time, three three each in two rows set back to back under three cutters. They are carried with the root bevel horizontally, and the pairs of blanks are run under the cutters after which indexing is done.

Fixture design has been, and is still being, greatly stimulated by the rapidity with which actual cutting operations are accomplished. This is not quite so noticeable in the ordinary operations of lathe, planer, and allied machines, using single-edged cutting tools, as it is in those where the individual tools have been multiplied, as in drills, and boring machines, and where continuous tooling is adopted, as in milling and grinding machines. The insertion of cutters of high-speed steel in face, edge and gang-mills has exercised a potent influence here. Obviously, when the actual time occupied in tooling is greatly reduced, the setting of the work in the fixtures must keep pace with it. Otherwise the performance of the tools will be checked, and the advantage of their use discounted. In many instances, therefore, although fixtures may have been designed to favour the most expeditious loading and unloading, the employment of a spare fixture or even sometimes more than one is necessary to keep abreast of the product of the tools.

Another aspect of the present subject is, that in highly repetitive manufacture, the fixture conjointly with the economies of multiple-tooling sometimes exercises a controlling influence on the smaller less important details of the articles manufactured. That is, if a simple scheme of tooling, and a more elaborated alternative one present themselves, the simpler will usually have the preference, provided always that efficiency is not sacrificed. Again, it is often deemed desirable to simplify unimportant details, not only with a view to reduce cost, but in order to synchronise the times of tooling—the time which individual pieces occupy in relation to the aggregate product. For if some one section of the mechanism lags, it will dislocate and hinder the work of the assemblers.

As firms become compelled by stress of circumstances to study the ways of their keener competitors, the reduction in the number of transferences between fixtures is adopted when practicable, and tracking, and conveying systems are installed, and single-purpose machines. Firms who adopt these methods undertake the manufacture of only one article, or one group of closely-related products, as motor vehicles of one kind only, or a single type of machine tool, or workshop appliance or equipment. A general class of manufacture is seen to be impracticable, inconsistent with the installation of these highly economical provisions, with which work done with even the aid of jigs and fixtures on standard machine tools is unable to compete. Equally good results can be achieved by either system, and interchangeability guaranteed, but the difference in cost is greatly in favour of the first. This indicates the character of the competition that will mark the immediate future, the specialisation round a single product, but one for which there is a large and a continuous demand sufficient to engage the whole energies of the firm for an indefinite time. By the substitution of mechanical aids for manual dexterity and muscular effort, labour costs are reduced. The attendants are mere units, enveloped by the system, their movements become nearly as automatic and precise as those of the machines and appliances they tend. No individual is in any degree indispensable. If he falls out, his place is quickly filled. But, fortunately for the monotony engendered, wages do not sink, but tend to increase with the growth of the product. Old hands do not take kindly to it, but this is the trend of successful manufacture in a worldwide field for competition.

The fact that great differences may be made in the character of the workmanship put into fixtures and jigs is helpful when firms desire to change over from the existing method to a better system. Provisions for location and for fastening may be crude and simple, or elaborate. Bushings can be cheaply made for a limited service, or measures can be taken to ensure prolonged life, and to facilitate renewals. A considerable portion of the expense of high-class jigs goes in quality of steels, and in hardening and grinding, in the fitting of slip bushes, in fine limits for tooling. Having regard to future developments which may not mature, cheap and temporary fittings may take the place of those which in a high-class plant cost considerably more. The degrees of inaccuracy permissible in different part should have their influence on economic design. Some dimensions are of small moment, others must be produced within fine limits. Thicknesses which are not working parts come in the first category. Many centres, overall lengths, diameters, and bores in the second. But in these the limits vary much, as they do in the numerous degrees of fits that are embodied in gauges. Time and expense are thrown away

when finer limits are included than are necessary, since fine limits increase the cost both of the jig or fixture, and of the tooling done on the work held. Limits of tolerance are determined for each detail, but they vary widely in different parts, as well as for typical groups of manufacture.

The bodies of all fixtures must be rigid enough to withstand distortion consequent on their own weight, or to the effects of clamping. But it is not well to increase weight unnecessarily. Lightening holes can be cast in the larger sizes, and these afford the additional advantage of permitting observation of the articles enclosed, and in many cases egress for the chips. When fixtures have to be manipulated by hand, reduction of weight is essential.

Large fixtures are iron castings, very small sizes are cut, or built up in mild steel. Aluminium is used to reduce weight. Spring must be avoided in designing the clamping arrangements as carefully as when work is bolted directly to a machine table. This may arise from insufficient or improper support rendered, from improper clamping, or from the pressure of the tools. The more flimsy the articles are, and the larger their areas the greater must be the care exercised in these details. The number of supports must be ample, preferably in some cases with spring resistances, and clamps must be tightened in direct opposition to the supports, or in the closest proximity to them. Support must be provided in very flimsy pieces to oppose the thrust of drills, or of milling cutters. Always provision must be included for the escape of chips. Using the high-speed tools the quantity of cuttings made by drills and milling cutters is very large. In some cases exhausting methods are employed, but gravity is usually relied on. In one case where multiple cylinders are being bored, an exhaust fan carries the chips into a box fitted with baffle plates. The bores and the machine are thus kept free from chips. Dust is carried away similarly from cylinder grinders.

As in other departments of machine-shop work, the growth of the jig practice is reacting on the designs of the machines. Since it pays to instal costly fixtures, machines must be employed capable of operating them to the fullest advantage, leading up from the standard general-purpose to the single-purpose designs. Since in these the human element is nearly eliminated, some of the expense incurred must be justly set off against spoiled work due to bad setting of work, tools, and so on. The expense is not all out of pocket even from this point of view. The increasing elaboration of the fixture and jig, with higher specialisation in manufactures, must inevitably exercise great influence on the future of machine-tool design. Object lessons emphasised during the late stress in the factories devoted to the production of shells, and of motors, will have powerful influences in shaping the policy of machine-tool managers in the pregnant future.

CONCRETE SHIPBUILDING AT BARROW-IN-FURNESS.

THE MOUCHEL-HENNEBIQUE SYSTEM OF SHIP CONSTRUCTION.

By W. NOBLE TWELVETREES, M.I.Mech.E., M.Soc.Ing.Civ.

For a period of several years before the outbreak of the war now virtually terminated, Messrs. L. G. Mouchel and Partners, Limited, of Westminster, had under consideration various projects for the employment of the Mouchel-Hennibique system of ferro-concrete to the building of ships, barges, pontoons, floating docks and kindred structures. Their belief in the structural and commercial practicability of the concrete ship was supported by the satisfactory results furnished by many years of boat and shipbuilding in France, Italy, Holland and elsewhere on the Continent, and by the excellent behaviour of the 200-ton pumping lighter built from their designs some six or seven years ago for the Manchester Ship Canal Company.

Some difficulty was experienced, however, in persuading shipbuilders and the Admiralty to make practical trial of a method of construction involving so great a reversal of preconceived ideas, and it was not until war conditions arose that naval architects and shipbuilders began to take the claims of reinforced concrete seriously into consideration.

One of the first evidences of practical action was the formation of the Ferro-Concrete Ship Construction Company, Limited, of Vickers House, Westminster. The company, which is carried on under the direction of Mr. T. G. Owens Thurston, director of naval construction to Messrs. Vickers, Limited, was founded for the purposes of acting professionally in the design of concrete ships, and of carrying out shipbuilding in the yard equipped at Barrow-in-Furness, in close proximity to the naval construction yard of Messrs. Vickers, Limited.

In the first instance, the newly-formed company decided upon the building of six cargo steamships of 1,150 tons deadweight capacity. These vessels were to be built as a private venture with the object of providing some of the additional tonnage urgently required by the country, and it was felt that the practical experience gained in the construction and by the behaviour of the vessels in actual service, would furnish valuable data as to the reliability of concrete ships, and the extent to which the dimensions of similar vessels could be safely increased in the near future.

The company possesses special advantages for the design and construction of concrete vessels. The directors and staff at Barrow, and in Westminster, are thoroughly versed in the art of shipbuilding, expert knowledge of reinforced concrete design is rendered available by the co-operation of Messrs. L. G. Mouchel and Partners, Limited, and valuable aid in the execution of reinforced concrete work is the result of an arrangement entered into between the company and the Yorkshire Hennibique Ferro-Concrete Contracting Company, Limited, of Leeds. Thus the Barrow shipyard is in an exceptionally favourable condition for the attainment of the best possible results, having at command the services of thoroughly experienced naval architects, civil engineers and practical constructors, working in collaboration.

Shortly after the company had selected the port of Barrow as a suitable place for the building of cargo steamships, and had secured an excellent site, the Admiralty Department, now under the Ministry of Shipping, instituted a comprehensive scheme for the construction in reinforced concrete of sea-going barges and steam tugs, and invited the co-operation of shipbuilding and contracting firms in the execution of the project.

The directors of the Barrow shipyard at once offered their services, and received authority for the building of ten 1,000-ton barges and six steam tugs of 750 h.p., approximately. Several firms of public works contractors, skilled in concrete construction, offered their services at about the same time, the result being the establishment of 20 or more Admiralty Extension Shipyards at seaports, or on navigable waterways near the sea, in England, Scotland and Ireland. Among these new shipyards, nine have been established and equipped by previously-existing or newly-formed companies working in association with the Mouchel-Hennebique organisation, and all these companies have the benefit of technical advice and assistance generally from the Ferro-Concrete Ship Construction Company, in respect of yard equipment, launching arrangements and other matters connected with shipbuilding, and from Messrs. L. G. Mouchel and Partners in respect of reinforced concrete work, all designs and working drawings for ships being prepared by the two firms acting in co-operation.

Thus it will be realised that the company to which attention is directed in the present article, has a far wider field than any of the companies whose activities are confined to operations in their individual shipyards.

Turning now to the establishment at Barrow, the present yard is situated on the banks of Walney Channel, on a derelict shipbuilding site, formerly occupied in part by a yard engaged in the building of wooden craft by the late Mr. David Noble. The site was occupied subsequently by Messrs. D. Caird and Sons, Messrs. Ashburner, and the Barrow Shipbuilding Company, who were engaged, some forty or fifty years ago, in building wooden schooners and small iron sailing ships and steamers.

The area at first acquired by the present company was merely intended for dealing with their original programme, but when the Admiralty scheme appeared, a considerable additional area was secured and laid out so that cargo boats, barges and steam tugs could be laid down and rapidly completed, to cope with the pressing need for tonnage.

Fig. 1 is a plan showing the general arrangement of the yard in its present condition. The yard has a wide water frontage to Walney Channel, and affords a very good launching ground. When taken over, the site was a practically waste area of land some 10 acres in extent. Some disused buildings near the sea front were removed to make room for shipbuilding berths, and other buildings, which at one time were well equipped with shipbuilding plant used by the previous owners mentioned, have been adapted for various purposes by the new company.

The site, which is well adapted for the purpose of building vessels up to 250 ft. in length, has been greatly developed, and the plant has been arranged so as to make the best use of the available space, both for the 12 berths shown on the plan, and in the provision of working spaces so that steel bars employed as reinforcement, and the materials for concrete making, can be conveniently dealt with.

As the requirements of the new branch of ship construction are far more independent of mechanical appliances and methods than those of steel shipbuilding, it has been possible to commence operations on a fairly large scale considering the area at disposal. Other advantages worthy of note in this connection are the standardised nature of the projected craft, and the unskilled, or semi-skilled character of the labour required.

In consequence of war-time restrictions with regard to man-power and the supply of structural materials of all kinds, a good deal of ingenuity and considerable engineering skill were entailed in coping with the construction of the foundations for building berths, and the execution of work in the channel to provide for the launching of vessels built.

Railway sidings were already in existence in some parts of the yard when the site was taken over, and with a few extensions these have provided useful facilities for the direct delivery of materials and supplies generally.

Spaces of ample area have been allotted for the storage of steel bars, as indicated at the left-hand of Fig. 1, and arrangements were made for storing all the bars of different lengths in suitable racks all clearly marked, in order to facilitate the ready selection of any sizes of bars required in the adjacent bar-bending department. Suitable shelter is provided for the men employed at the bar-bending machines, and every convenience exists for the supply of information as to the form to which the bars are to be bent and for ensuring the accuracy of the work. A large building previously on the site has been adapted for use as administrative offices and stores, while an adjoining building has been renovated and occupied as a joiners' shop, a mould loft where full-size sections of ships can be drawn on the floor, and a cement store.

Further storage room for cement is provided in a shed specially built for the purpose near the building berths, and adjoining it is a testing laboratory, where attention is given daily to tensile tests of cement, compressive tests of concrete cubes, percolation tests of concrete slabs and determinations of the proportions of voids in sand and aggregate as a guide to the grading of these constituents in such manner as to produce the highest possible quality of concrete.

Sand and aggregate are stored at the two ends of the yard, and are conveyed by means of contractors' railway lines to the several concrete mixers installed near the various groups of berths.

Heavy forgings, castings and steelwork required for special details, such as stern posts, hawse pipes, bollards, stanchions, &c., are obtained from outside firms, but other iron and steel work is carried out at the yard, where in addition to the bar-bending department mentioned, there are also a well-fitted smithy with six hearths, and a mechanics' shop, about 100 ft. long by 30 ft. wide, equipped with lathes, drilling machines, screw-cutting machines and other tools.

CONCRETE SHIPBUILDING AT BARROW-IN-FURNESS.

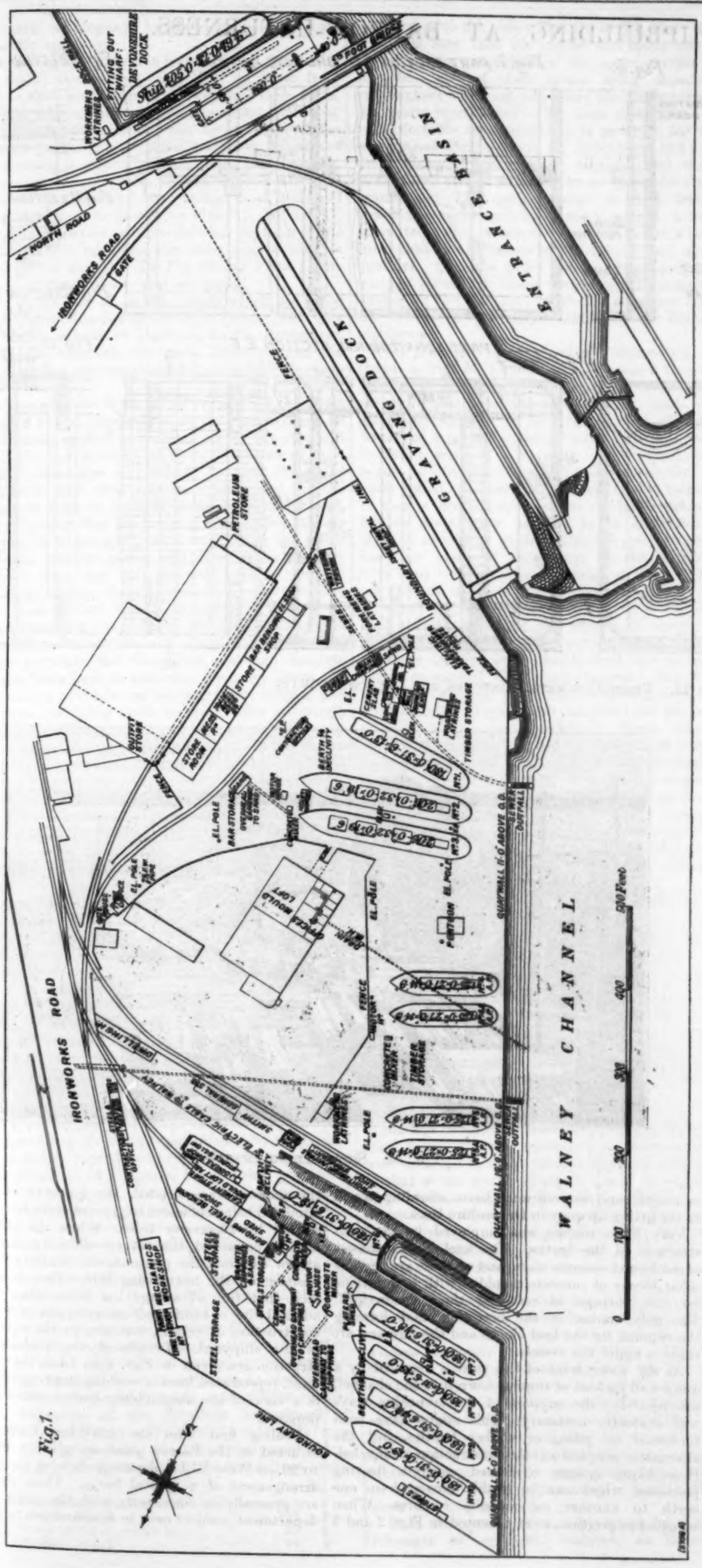


Fig. 1.

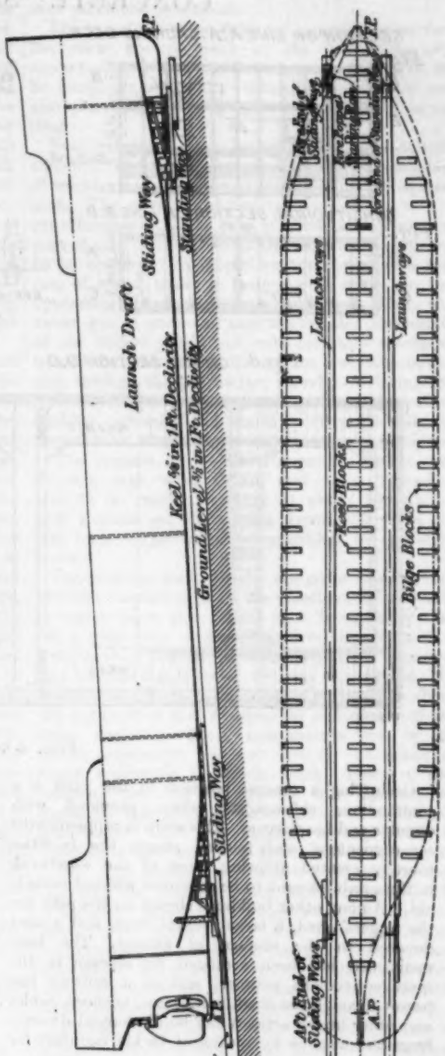


Fig. 2.

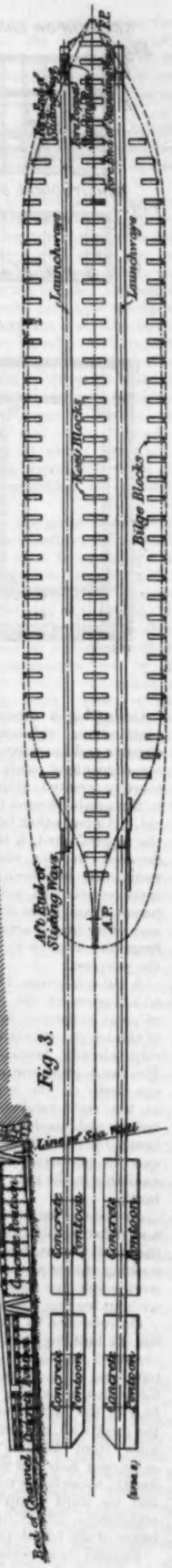
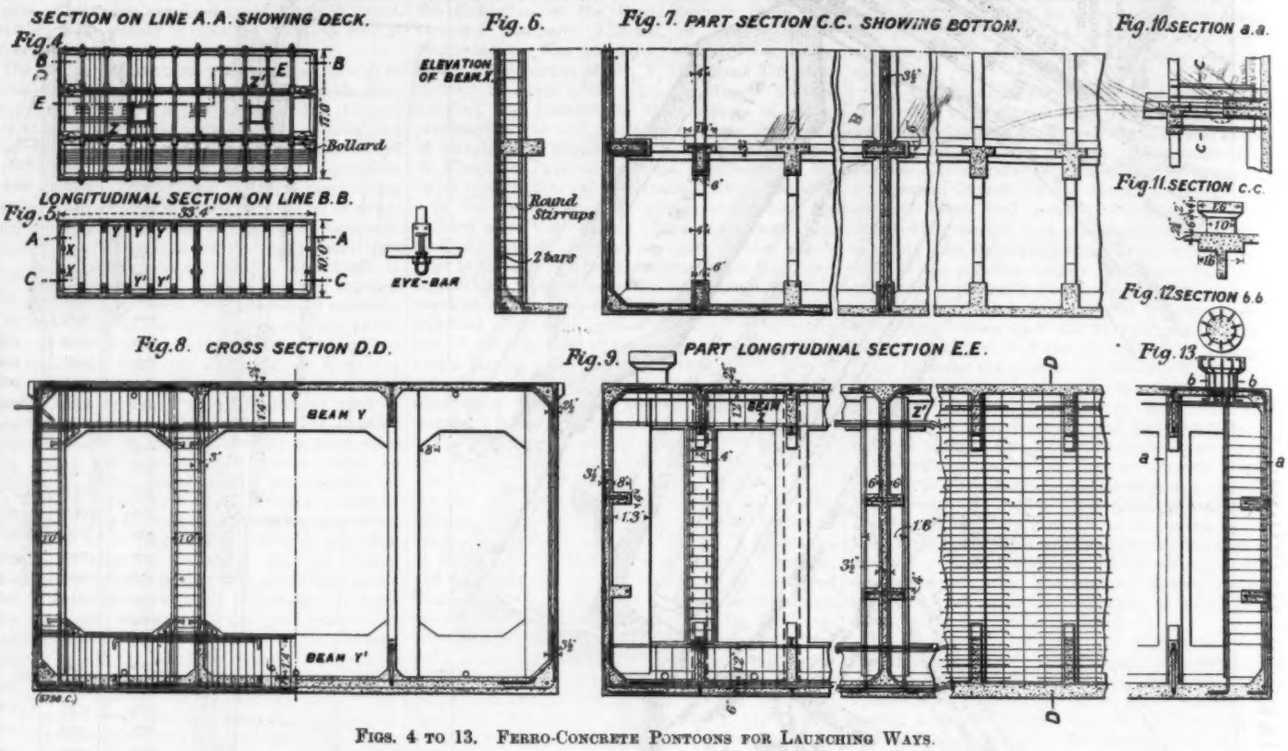


Fig. 3.

CONCRETE SHIPBUILDING AT BARROW-IN-FURNESS.



FIGS. 4 TO 13. FERRO-CONCRETE PONTOONS FOR LAUNCHING WAYS.

Occupying a central position in the yard is a commodious shipwrights' shop, provided with circular and band saws. This shop is supplemented by carpenters' and joiners' shops, the facilities thereby created allowing most of the woodwork in the establishment to be executed without outside aid. Among other buildings shown on the plan are the riggers' shed, a large general store, and a shed devoted to the storage of fittings. The last-mentioned has been arranged for storage in the most convenient manner, and as a railway line passes through the shed, windlasses, anchors, cables and other heavy articles can be discharged directly from the wagons by means of tackle installed for the purpose.

A 10-ton crane travelling on tracks extending to all parts of the establishment, has been found of great assistance in connection with the building of the barges, steam tugs and the first cargo steamship already launched and under construction. The same crane can also be travelled to the fitting-out berth on the west quay of Devonshire Dock, at the right-hand of Fig. 1. Here the fittings, boilers and machinery for vessels can be lifted on board by the crane, and exceptionally heavy lifts can be performed by a 30-ton crane, which is available in the immediate vicinity of the fitting-out berth.

In concluding this brief sketch of the buildings and other auxiliaries in the yard, mention may be made of the canteen and mess-house, fitted with cooking stoves and all requisite utensils, where the workpeople are able to take their meals in comfort without leaving the works.

On reference to the plan it will be observed that the 12 building berths at present in existence are arranged in three groups. Commencing at the left hand of the plan (Fig. 1) there are five berths for barges, measuring 180 ft. between perpendiculars, four of the berths being on the open space behind the quay wall, and one in a cutting at the head of an inlet from Walney Channel. The next group comprises four berths for steam tugs, 125 ft. in length, these being on ground behind the quay wall, and the third group includes two berths for cargo steamships, 205 ft. in length, and one berth for a barge of the length previously stated.

Beyond these berths are a dry dock about 500 ft.

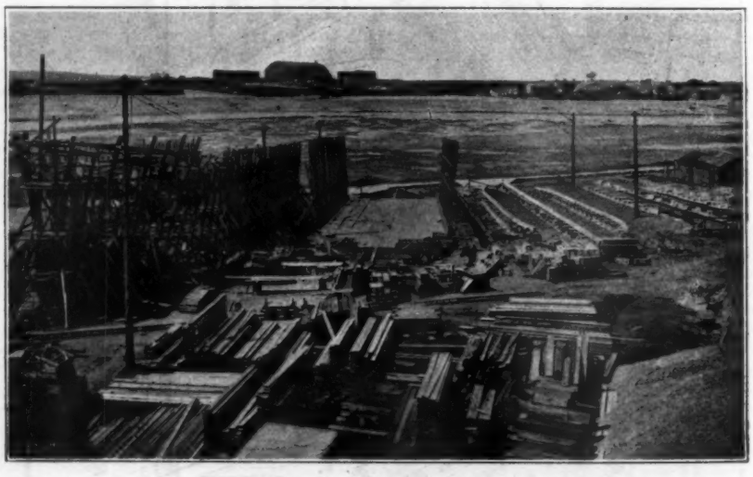


FIG. 14. SHIPBUILDING BERTHS.

in length, and the entrance basin affording access to the fitting-up quay in Devonshire Dock.

Very little timber was employed in the construction of the berths. The keel blocks consist of reinforced concrete slabs, and on these are vertical pillar blocks of concrete moulded with perforations for the purpose of reducing their deadweight. The only timber in the berths is that forming the capping for the keel blocks and the fore and aft runners under the vessels.

As the water front of the yard is bounded by a quay wall instead of sloping down into the channel, provision for the support of the launching ways was evidently necessary. This might have been furnished by piling or timber trestles, but the alternative adopted was the construction of Mouchel-Hennebique system reinforced concrete floating pontoons, which can be readily moved from one berth to another as occasion requires. When adjusted in position, as represented in Figs. 2 and 3 the pontoons are flooded, the quantity of water admitted being sufficient to prevent them from being shifted by successive tides. When the pontoons have to be moved, the water is allowed to drain out at low tide and the pontoons are floated to a new position on the next rising tide. Thus it will be seen that full advantage has been taken of the adaptability of reinforced concrete, not only in the construction of vessels, but also in the equipment of the shipyard. Details of the pontoon construction are given in Figs. 4 to 13 on the present page, reproduced from a working drawing. Fig. 14 is a view of the shipbuilding berths with work in progress.

Dealing first with the 1,000-ton barges constructed at the Barrow yard, we give in Figs. 15 to 20, on Plate XLIX, drawings showing the general arrangement of a typical barge. These drawings are generally in conformity with the plans of the department, subject only to modifications in respect

of details, as proposed by the designers, and subsequently approved.

Measuring 187 ft. 6 in. in length overall, 31 ft. 6 in. in breadth at deck level and 19 ft. in depth from deck to keel, each barge of this type has three holds, the fore peak containing accommodation for stores, chains and cables, while the deckhouse includes quarters for the captain, mate and crew, and spaces occupied by a steam boiler, pumps, coal bunkers, tanks and other parts of the equipment. The positions of the deck-house, bridge, boat deck and steam winch are indicated by Figs. 15, 16 and 17, Plate XLIX, whilst sections showing the form of the vessel at bow, midships and stern, will be seen in Figs. 18, 19 and 20. In Fig. 23, on Plate L, the details of the reinforcement are shown.

As in the case of all the vessels which are being built on the Mouchel-Hennebique system, not only at Barrow, but also at Aberdeen, Amble, Barnstaple, Gloucester, Gourock, Greenock, Queenborough and Warrenpoint, the construction is monolithic throughout.

Although the system of reinforced concrete adopted at the shipyards in all these ports could be quite easily applied to building on the pre-cast unit principle, as it actually has been in the case of some marine structures and railway bridges, the naval architects and civil engineers associated in the design of ships to be built at the yards mentioned, are of opinion that the hogging and sagging stresses developed in sea-going craft may cause the joints between pre-cast plates and other units to work loose in time, and that the steel used in the construction of units, being necessarily in short lengths, cannot be utilised in such an efficient manner as it can be where the skin of the hull is monolithic with the transverse frames and longitudinal members. They entertain the view that, although concrete vessels have been in existence for many years, the application of reinforced concrete to the construction of large sea-going craft involves some extremely complex problems, which can only be solved by the fruits of practical experience, and that in the present state of the new industry it would be inadvisable to depart from the monolithic principle which has proved itself to be so efficacious in securing unity of action between the elements of important structures on land.

Briefly outlined, the procedure adopted at Barrow is as follows: The outside shuttering for the hull is first erected complete, in the interior of this shell the reinforcement for skin of the vessel and all the members of the framework is assembled and secured in position. Fig. 14 is a view of the barge berths illustrating two stages in the erection of the shuttering; when all is ready the operation of concreting is commenced and continued as far as practicable without a break, the construction of the decks and upper works (Fig. 22) being undertaken when the hull is nearing completion. As soon as the concrete has set sufficiently, the shuttering is removed, and the vessel is ready for launching after the concrete has thoroughly hardened.

The arrangement and relative dimensions of the longitudinal and transverse members of the framework are shown in Figs. 15 and 16, and the particulars there given are supplemented by the typical cross-section reproduced as Fig. 23. This represents the details in 31 frames in the midship portion of a 1,000-ton barge, the same general method of construction being applied to the fore and aft peaks, subject to the modifications rendered necessary by the varying form of the cross-sections.

Fig. 21, on Plate L, is a view showing one of the barges berthed alongside the fitting-out quay in Devonshire Dock. It may be added that the two launches have entirely justified the employment of the reinforced concrete pontoons for the support of the standing ways, as described earlier in this article.

The steam tugs will be very smart-looking craft bearing an even closer resemblance to steel vessels than those of the barge class. As will be realised on inspection of the drawings reproduced on Plate LI, the tugs will contain a relatively large amount of engineering plant and equipment.

The general dimensions of the steam tugs are:—

	Ft.	In.
Length between perpendiculars ...	125	0
Length overall	132	0
Beam on 12-ft. water line	27	6
Moulded depth	14	9

Referring to the views Figs. 24 to 27, Plate LI, it will be seen that the engine and boiler rooms occupy a large proportion of the space amidships, on either side of these rooms being capacious coal bunkers which can be readily filled by means of the shoots represented on the main deck plan.

Comfortable accommodation is provided for the captain and officers fore of the boiler-room and over the feed-water tank, store, magazine and chain locker, and the crew's quarters are over the shaft tunnel aft. The central range of deck houses comprises engine and boiler-room casings, a well-appointed galley, steam steering gear cabin, a large coal shoot and entrances to the officers' and men's quarters. Over the galley are the wheel-house and wireless room, the latter with sleeping accommodation for the operator, above the structure being the bridge and on either side of it the lifeboat platforms.

The principal members of the framework are shown in Fig. 24, where it will be noticed that the spacing of the transverse frames is varied from point to point conformably with the loads and calculated stresses to be resisted. Fig. 28 gives details of a typical midship frame, half of it being in section and half in elevation. The central space is occupied by the engine and boiler rooms, and the outer spaces are those provided for the coal bunkers. It may be pointed out that the reinforced concrete bunker construction appears to be analogous to that of a tubular girder, although no advantage has been taken of this factor by the designers, who have wisely decided to take no risks and to err, if at all, on the side of safety. No steam tugs have, so far, been completed, but it is expected that several vessels of this class will shortly be launched, although they will not be built at Barrow.

Before deciding to commence their first sea-going cargo steamship, the Ferro-Concrete Ship Construction Company made careful investigation into the suitability of reinforced concrete from the point of view of the naval architect. Being satisfied on this point, they decided to design and build a self-propelled cargo vessel of 1,150 tons deadweight capacity as a first venture. The designs represent the results of collaboration on the part of experienced naval architects and reinforced concrete engineers, and the practical construction has been carried out under the joint direction of managers and superintendents skilled in shipbuilding and reinforced concrete work, respectively.

The dimensions and general particulars of the vessel are:—

	Ft.	In.
Length between perpendiculars ...	205	0
Breadth, moulded	32	0
Depth, moulded	19	6
Draught, loaded	16	0
Horse, power, indicated	350*	
Speed in knots	7½*	

* Approximate.

Figs. 29 to 32, Plate LII, include plans and a longitudinal section of the ship, and Figs. 33 to 37 are a cross-section and some of the more important structural details.

The various arrangement drawings were prepared in the first instance on the basis of Lloyd's Rules for Steel Ships, and the reinforced concrete members were designed so as to provide strength equivalent to that of the members which would be employed in a similar vessel built entirely of steel. The design was afterwards reconsidered, due regard being given to the longitudinal and transverse stresses which might be expected to be developed during construction and launching, and in actual service.

Having regard to the fact that the hull had to be moulded entirely in shuttering, a midship section was adopted having straight sides, and the bottom without curvature except at the bilges. This form of section was applied to about half the length of the vessel, the waterlines fore and aft being rounded as shown by the drawings, but the straight-line sections were retained as far as practicable. The ultimate form of the hull was determined by the aid of trials in the experimental tank, and as finally settled was found to be approximately equivalent to that of an ordinary steamship of similar dimensions and displacement.

It is unnecessary to occupy space by detailed reference to structural features, as these are essentially similar to those of the barges and steam tugs previously described.

The vessel has three holds for cargo, quarters for the crew are provided in the forecastle, and accommodation for the captain and officers is to be found aft, where the boilers and machinery are also placed, as quite usual in vessels of the same class.

Two cylindrical steam boilers have been installed, each 9 ft. long by 9 ft. 6 in. in diameter, and capable of working at a pressure of about 130 lb. per square inch. The adoption of two boilers was due to the considerations that in case of a breakdown on the part of one, the other would still enable the engines to be employed in propelling the vessel at a fair rate of speed, that one boiler would suffice for the operation of all auxiliary machinery while the vessel was in port, and that the smaller dimensions of the boilers would not only facilitate transport by rail, but also permit them to be lowered into the ship through the hatchways, thereby obviating the necessity of leaving part of the reinforced concrete decking unfinished, as would in all probability be unavoidable if one large boiler had been adopted.

The engines are of the compound surface-condensing type, with 17 in. and 34-in. cylinders and 24 in. stroke, working at about 100 r.p.m., and capable of developing from 350 i.h.p. to 400 i.h.p. The vessel is propelled by a single screw.

Calculations made by the designers showed that the load displacement of the vessel would probably be rather more than 25 per cent. in excess of that for a steel ship, and slightly less than that of a wooden ship, both of the same deadweight capacity, and similarly equipped. On the other hand, the amount of steel was calculated to be only about 42½ per cent. of that required for a steel ship of the same capacity. These comparisons are by no means conclusive, and can scarcely be taken as fairly applicable to future work. Being a first venture, the ship in question was designed on distinctly conservative lines, and it is confidently anticipated that considerable savings will be possible in the weight of both steel and concrete.

The first steamship completed at Barrow was launched in January last and christened the Armistice. After performing her trial trips in a satisfactory manner, she was sent to Ireland, encountering exceedingly rough weather, and afterwards brought a cargo of grain to London, where she attracted a good deal of attention as the first concrete ship to enter the Thames.

Shortly after her arrival, the writer had an opportunity of inspecting the Armistice in Millwall Docks, and was informed by the captain that the behaviour of the vessel in heavy seas was perfectly satisfactory, one particularly noticeable feature being a complete absence of the customary vibration. Owing to the greater load displacement of the vessel in comparison with that of a steel ship of equal deadweight capacity the cargo of grain brought to London was stated to be 900 tons, or 200 tons more than could have been got into a steel vessel of the same deadweight capacity. Thus the economy of the concrete ship for light and bulky cargo becomes evident. Naturally, if the cargo is heavy in relation to its bulk, the steel ship possesses an advantage.

Since her first arrival in the Thames, we understand the Armistice has been regularly employed in carrying cargo to and from the Continent, behaving well in every respect and proving a remunerative investment for her owners.

THE IRON AND STEEL INSTITUTE.

(*Continued from page* 612.)

IN our last issue, we reported the preliminary proceedings of the Iron and Steel Institute. It was also announced at the meeting of Thursday morning, the 8th inst., that the Worshipful Company of Blacksmiths had on October 3 last, passed a resolution to the effect that the Freedom of the Company, together with a gold medal, bearing the Arms of the Company, be presented annually to a student or to a contributor of a paper to the Iron and Steel Institute. It was also announced that congratulations had been sent in by the London

Institution of Mining and Metallurgy and the Institute of Metals, on the occasion of the Iron and Steel Institute's Jubilee.

THE BELGIAN IRON AND STEEL INDUSTRY DURING THE GERMAN OCCUPATION IN THE GREAT WAR.

The first paper taken at Thursday morning's meeting was one having the above title, by Mr. Léon Greiner. It was read by his brother, Mr. Auguste Greiner, and we reproduced it in full on page 618 of our last issue.

The chairman thanked the author for his contribution and said that one could not help but feel both deeply grieved at the mention of such horrors and atrocities as those laid to the charge of Germany, and ashamed for mankind that such atrocious deeds should have been committed. He hoped the full knowledge of the situation had come before the Peace Committee.

Dr. Arthur Cooper mentioned the visit he paid to the Cockerill establishments before the war, where he saw most interesting work; they were a hive of industry. He was very much struck by the extent of devastation that had been carried out by the Huns, and all would agree that the Cockerill Company deserved the greatest sympathy. At the same time, the Institute strongly applauded the great resourcefulness which had been shown by the managing staff who, also, deserved the highest congratulations for having produced manganese, silicon and other alloy steels under such difficult circumstances.

Mr. F. W. Harbord, who followed, said he had recently been in Belgium and had visited Seraing and two other works. When one could see the systematic way in which destruction and plundering had been carried out by the enemy, one could then, and only then, realise what had been the sufferings of the population. The destruction work had been done deliberately; for example, engines had been removed bodily and the foundation bolts bent over and left in. Reconstruction of the former establishments would be a very complicated task, and would in many instances take longer than if new works were put down on a new site. The loss of business to the Belgian nation was a most serious consideration, and he (the speaker) expressed the hope that the works themselves would not only be replaced, but whilst that was being carried out, Germany would be made to supply material also. It was, however, very difficult to see how any compensation and reinstatement could make up for all the losses which had been sustained.

Mr. Richard Mather stated that he had formed part of a Commission which had recently travelled through Belgium after having visited steel works in Germany and Luxemburg. He had been to the Cockerill works and could say that the extent of the damage done there was simply appalling. The greater part of the works had been destroyed, and what did remain had been rendered incapable of further action for the time being. The Belgian works owners would be fortunate indeed if they succeeded in getting 25 per cent. of their pre-war output within the next twelve months. The loss to the Belgian nation was most serious, and no money indemnity and no recovery of plant could completely indemnify the Belgian works, and those in Northern France, for the damage done by the German hordes. It was a point of duty for British and American iron and steel works and engineering establishments to give priority of supplies to those devastated districts so as to enable works to rapidly start afresh. Whilst he was in Germany he had heard of a scheme which had been evolved for erecting blast furnaces on the Rhine; he was told that the plan in question had not then fully matured, and his German informant added that he did not know whether the proposal would now be carried out, since the general situation was not settled. A week later, he (the speaker) went through Liége to Valenciennes and found, when in the latter city, that the blast-furnace plant which the Germans contemplated putting down on the Rhine was being taken from the Aciéries du Nord et de l'Est. They had taken the greater part of the plant appertaining to one furnace and were just commencing to take to pieces the plant of a second when the armistice came. This emphasised the extent and the thoroughness of the damage done by the enemy. He agreed with Mr. Harbord that in many instances it would be easier to begin a new works on a new site than to reconstruct an existing works which had been so systematically and so ruthlessly destroyed.

On the motion of the chairman, the author was awarded the cordial thanks of the Institute for his contribution.

USE OF PULVERISED COAL, WITH SPECIAL REFERENCE TO ITS APPLICATION IN METALLURGY.

The next paper taken was one by Mr. L. C. Harvey, dealing with the application of pulverised coal to metallurgical work. It was read in abstract by the author, and we intend to reproduce it in an early issue.

Mr. Quigley, several of whose installations in the United States are referred to in the paper, said he had given every opportunity to the author for investigating his apparatus, and felt sure other works who were dealing with the use of powdered coal did the same.

Mr. B. Talbot regarded the paper as showing that metallurgists were endeavouring to go back again to crude coal for some of the main operations in the manufacture of iron and steel. But the political experts of the present day would not allow metallurgists to extend the direct use of coal owing to the loss in by-products which would be incurred thereby. He did not wish to disparage the great development referred to in the paper, but thought that the reversion to raw coal in the open-hearth furnace might be considered a retrograde step. In the subsequent operations carried out on the ingot, the use of powdered coal might be another matter. He (the speaker) expressed the hope that no other coal fuel would be used in metallurgical work apart from that required to charge the coke ovens. He hoped also that all the steel made would be obtained starting from the liquid iron proceeding from the blast furnaces and that coke would be the only fuel used as far as the making of the ingot was concerned. An interesting point suggested by the paper was that the quality of the coal seemed to be immaterial; if this worked out to be true it would be an exception, and the only exception known.

Mr. G. Carrington asked what would be the effect of the use of powdered coal on the product from the puddling furnace and whether a more or less large proportion of ash might not mix with the iron. The ash might also have an effect on the material placed in the reheating furnace. The coal now available for metallurgical operations was bad coal, and it had, moreover, become three to four times dearer than formerly. It would be necessary therefore to look forward to deterioration caused by the ash, and this would be a serious point.

Professor Louis asked whether it was necessary for the coal to be freshly ground, for if it were possible to use coal dust not freshly ground there were great possibilities in store for the process. Coal dust was made in considerable quantities in coal-mining, and everybody knew that coal dust was to-day the greatest enemy in collieries. It was possible by a systematic process of dry-blowing on a large scale to separate coal dust from stone dust and thereby to obtain pure coal dust cheaply. If it were possible to use coal dust from the mines the process would introduce a great feature, since it would convert into money what was now a great nuisance and a great source of danger.

Mr. H. M. Ridge found the process referred to by the author a most interesting one, and one which might lead to economy in fuel in the smelting of steel and non-ferrous metals. He thought emphasis should be laid on the fact that it was necessary to eliminate the impurities in the coal dust used for firing furnaces. He thought the heat curves showed rather extraordinary results, a high flame temperature with an increased ash content. The use of powdered coal high in ash would, among other considerations, interfere with the quality of the product and also with the life of the refractories. Powdered coal high in ash used for smelting would add to the expenditure.

Mr. J. H. Harrison asked the author where the report he referred to (Department of Scientific and Industrial Research. Fuel Research Board. "Pulverised Coal Systems in America," by Mr. L. C. Harvey) was published. The use of powdered coal might in one sense be considered a retrograde step for those works who owned blast furnaces and had gas at their disposal, but there were other works in which it could be used.

Dr. W. H. Hatfield, who followed, said several people stated the process to be new; he (the speaker) was in the United States in 1908, when he saw applications of the process and was impressed by its apparent heating efficiency. The question of the ash and its possible action was one to be considered, and he had not had the opportunity to investigate that point. For the last eleven years, therefore, the process had been applied commercially in the United States. He would like to know the number of plants and furnaces where the process had been taken up.

Mr. H. H. Hayes said that in the furnaces for non-ferrous metallurgy which were coal-fired it was frequently difficult to control the temperature in various zones; the control would appear to be an easier matter with the coal-dust process.

Mr. F. W. Harbord agreed with the remarks made by Mr. Talbot, but he thought the system might find application in establishments which had no blast furnaces. There was no question but that if with powdered coal the heat could be utilised exactly where it was wanted, there was the saving of the conversion into gas in the gas producer. The process would not compete in those cases where available gas was at disposal, but in those where one had to rely on the gas producer. The heat efficiency must be a very high one; the use of powdered coal in cement manufacture was considered more efficient than the use of gas. The author had referred to screw feeders, and his (the speaker's experience in this respect was that the feed should only be carried out at half the rate, otherwise jamming was liable to occur, and great regularity in the feed was an important point. It was not possible to use coal of low value to do highly efficient work in the open-hearth furnace; one of the difficulties encountered would be the accumulation of ash in the chequers.

Mr. J. E. Fletcher said that owing to the labour difficulty in connection with puddling work many were looking forward to the development of mechanical puddling; Crampton many years ago, in mechanical puddling, used powdered coal. Referring to the author's diagrams showing the flue gas analyses in the case of puddling furnaces with powdered coal firing and hand-stoking, he questioned the author as to control in combination with high yield, and asked whether the use of powdered coal in America was becoming general and was attended with uniform success. With reference to the impurities in coal, the trouble in the Black Country was that they had a coal yielding a high percentage of lime ash, and the use of coal which gave a quantity of ash having a high percentage of lime was surrounded with difficulties from the point of view of temperature efficiency.

Sir William Beardmore stated that he had considered the subject, which was one of great general interest; many arguments could be adduced in favour of the process and many against. Several months ago, he had received data on the process from the United States from works which had been using it for the last three or four years. He had been struck by reading the information sent him and had decided to put down an experimental plant and to thus prove the process. The plant was now being built, and he hoped it would be in working order in about three months. When he had obtained results he would be very pleased to put them before the Institute.

Mr. E. B. Christmas said the use of powdered coal was satisfactory in rotary cement kilns, but the concensus of opinion was that it was not satisfactory in steel-making; since the chequers of the open-hearth furnaces would rapidly clog up. Given the few inches of water pressure at which the powdered fuel was to be fed into the furnaces, he did not see how the ash could be prevented from getting into the furnace.

Mr. R. Hutchinson said that Mr. Talbot had

already stated the case as he (the speaker) would have put it. If the coal could be washed at the works, used in the works' coke ovens, the by-products being recovered, and the coke-oven gas then utilised, that would be the most economical means of working, and to use powdered coal direct in the furnaces would be a retrograde step. Where, however, no blast furnaces were available, the use of powdered fuel, as other speakers had said, would be of advantage. A steel works would have to be located invariably in close proximity to blast furnaces, and it was incumbent upon them to remove all by-products from the fuel before this was utilised for metallurgical purposes.

Mr. Harvey, the author, said that many points had been raised in the discussion, he asked that more should be raised by correspondence and he would reply fully in writing. The development in the use of powdered coal did not lie with him. There had been a question of late of studding the country with a large number of super-power central generating stations, but he thought that many years must elapse before these would be supplying current. When the energy available in the coal is converted into electrical energy, matters will be different, that time, however, was still, he thought, a long way off. In the meanwhile there was a possibility of saving now 50 per cent. of the fuel used in some furnaces. Mechanical puddling had been referred to; an American firm had investigated the point and had arrived at the decision that mechanical puddling cannot yet be successfully accomplished. The said firm had then put down the powdered coal process in connection with their hand-puddling furnaces and had thereby effected a very large annual saving. Much information on the subject under discussion was given in his (the speaker's) report above referred to, and also the opinion of actual users. In the matter of the ash in open-hearth furnaces, the ash passed through the furnace and went to the chequers, which were provided with removable slag bogics. When open-hearth furnaces were designed, in the first place, for the use of powdered coal, the necessary provision could be made for collecting the ash; if existing open-hearth furnaces designed for using gas were transformed for using powdered coal, then trouble would be liable to occur in the chequers leading to their renewal. It was hoped that 500 heats could be got out of the furnace in America before it was necessary to clean out the chequers, and this was about the average for a furnace using producer gas. Any grade of carboneous fuel could be used. Where low-grade fuel was available and there was difficulty in obtaining better supplies, the process was the best way of getting out the full heat value from the fuel. In Brazil, they had been running locomotives for the last two years, on powdered fuel, and previously to that Welsh and other coal had to be imported into the country. They had in Brazil a low-grade fuel which they pulverised for the purpose, and if the statement which had been given him was correct, 250 locomotives burning powdered fuel were going to be put on the Brazilian Railways. In other places, pulverised peat and pulverised bituminous coal were being used together. Pulverised anthracite culm had been most successfully used under stationary boilers; this was the anthracite washing from the anthracite mines which was formerly a refuse, and was probably the lowest grade of fuel available. There was not much deposit on the product in the reheating furnaces.

The author was awarded the thanks of the meeting for his contribution.

The afternoon of Thursday, the 8th inst., was set apart for a joint session by invitation of the Institution of Electrical Engineers, to discuss papers on Electric Steel Furnaces.

Mr. Schneider said the Iron and Steel Institute were glad of the opportunity to have a joint discussion with the Institution of Electrical Engineers, to whom they were greatly indebted for the improvements carried out in the electric smelting of steel. He asked Mr. C. H. Wordingham, the president of the latter body to take the chair.

Mr. Wordingham was very grateful of the honour conferred upon him by co-operating with Mr. Schneider, who had taken such a prominent part in the fight put up by our Ally against the more than brutish Germans.

At the present session, inventors and builders of electric furnaces had come together with steel manufacturers; the former wanted to know what the furnace users had to say in the matter, and the users wanted to hear different points from the builders of furnaces. They had before them a series of six interesting papers. Sir Robert Hadfield had worked hard on the subject of electric smelting of steel and had been largely instrumental in arranging for the joint session.

Electric Furnaces.

The papers before the meeting were by Mr. W. K. Booth, on "The Booth-Hall Electric Furnace"; by Mr. A. Sahlin, on "A New Type of Electric Furnace"; by Mr. V. Stobie, on "Large Electric Steel-Melting Furnaces"; by Mr. J. Bibby, on "Developments in Electric Iron and Steel Furnaces"; and by Mr. H. A. Greaves, on "Application of Electrical Energy to the Melting of Metals." We commence printing these papers in the present issue, and need not refer to them now.

A sixth paper was by Mr. R. G. Mercer and dealt with "Electric Furnaces in the United Kingdom, 1918." It contained a large number of statistics and tables, from which we take the following:—

Table I.—*Electric Steel Furnaces in the United Kingdom.*

Make.	Number of furnaces.	Total Tons, Size.	Total k.v.a.	Nominal Tons Output per Month.
Electro-Metals ..	27	78	20,274	6,740
Greaves-Etchells ..	26	64½	18,930	5,680
Héroult	45	180½	43,220	13,760
Rennerfelt ..	4	7	1,895	750
Snyder	6	9½	3,150	1,200
Special	2	2	750	280
Stassano	2	2	600	240
Stobie	5	45½	10,050	2,600
Total ..	117	384	98,769	31,250

Table II.—*Electric Furnaces for Castings (Installed).*

Make.	Number of Furnaces.	Tons Size.	Total k.v.a.	Tons Output per Month.	
				Nominal	Actual.
Electro-Metals ..	13	25½	8,139	2,900	—
Greaves-Etchells	4	7	2,050	700	—
Héroult	7	16	4,150	1,560	—
Rennerfelt ..	2	5½	1,100	440	—
Snyder	6	9½	3,150	1,200	—
Special	2	2	750	280	—
Stassano	2	2	600	240	—
Stobie	1	5	800	400	—
Total ..	37	72½	20,739	7,720	5,019

The paper dealt also with the electric furnaces for castings to be installed, 11 in number, 44 tons total size, 12,200 k.v.a., having a total nominal output per month of 3,120 tons and an actual output of probably 2,028 tons. Further tables were also given on the electric furnaces for ingots installed (56 in number, for a total of 217 tons); on furnaces of this latter type to be installed (seven for 44·5 tons); and separate tables for output, &c.

The discussion was opened by Mr. F. W. Harbord, who thought that from the point of view of the steel-maker all the furnaces referred to were very similar, there was practically no difficulty in melting scrap in the furnaces, economy varying with the tilting and the other mechanical details. The real difficulty was in connection with the electrical connections, and in this matter he could not say which was the best system; all had their advantages and disadvantages—it was a purely electrical question. During the war many and all types of furnaces were used, but they had seen that the induction furnace had not been able to hold its own. The advantage was with the electrode type of furnace, but the electrodes had as a result the weakening of the roof, and a problem for the electrical engineers was to design a furnace metallurgically sound whilst doing away with the electrodes. The electric furnace was useful as a refiner of Bessemer metal. This metal could be over-oxidised, but if it could be treated in the electric furnace for a comparatively short time it could be practically deoxidised and the resulting product was equivalent to the very best open-hearth steel. Whether open-hearth steel, or Bessemer metal treated in the electric furnace were used depended upon the grade of ore available and the current consumption in the latter furnace. With regard to the reduction of iron ore, the electric furnace to act in the capacity of a blast furnace, there were many disadvantages connected with the scheme, and there had not been in practice the progress that had been anticipated under this head several years ago. He (the speaker) had seen the installation at Trollhattan, but its output was extremely small. In the making of pure iron, in places where cheap power was available, the "electric blast furnace" could compete with the charcoal furnace, but at those places only.

Dr. Stead advocated the working of the open-hearth furnace in conjunction with the electric furnace. In the basic open-hearth process, sulphur and phosphorus were left in the steel; if this was transferred into the electric furnace, the sulphur and phosphorus would be eliminated and the steel finally obtained would be superior to any other. That was the direction in which basic steel would be made in the future.

Mr. A. G. Ellis said the statement of the number of furnaces in this country and their output formed an interesting record. It was the first comprehensive record since an article he had seen some time ago in the German *Electrotechnische Zeitschrift*, which made no reference at all to the production of electric steel in this country. The figures for the British production quoted by the authors showed the progress which we had made. The question of the furnace sizes was one that was receiving attention. The electrodes constituted a limiting factor, and he asked the authors what progress they anticipated in this direction. He (the speaker) had designed transformers to deal with a 50,000 ampere current and told the steel makers that they could look for progress in that respect; there was now practically no limit to the size to which transformers could be built. He was interested at the emphasis which the authors had laid on the transformer equipment; it was paramount in this respect to have a sound job, and he pleaded for greater simplicity in the tapping. Mr. Stobie had stated that the heart of the electrical equipment of an electric furnace installation was the transformer; that was quite true, but the regulating switchgear was a complicated piece of apparatus and more liable to give trouble than the transformer itself. Mr. Stobie, also, had stated seven points as the requirements to be met in the design of transformers; he (the speaker) agreed with him in this respect, but thought that some members would here join issue, and he asked that the furnace makers should give the details of the conditions, rather than specify how the manufacturers of transformers should arrive at these conditions. Short capacity in transformers led to failures, the transformer plant not being sufficient for the load put upon it. Many developments had been carried out by trial and error; the voltage had first been fixed and ultimately altered, there resulting an overload instead of the conditions for which the apparatus had been designed. The furnace builders had now gained much experience, and it should be possible to obtain final figures from which to work. Mr. Stobie had recommended the bracing of all sides of the windings of transformers; this was not desirable or necessary, for the direction in which the windings tended to move could be determined, and they could be braced in any place where stresses tended to occur. He (the speaker) had dealt at some length with the point in a paper he had read before the Institute. He finally recommended greater simplicity in design, one or two tappings only for voltage regulation and the placing of all regulating tappings outside the transformer proper, so that should the regulating gear break down, the transformers could still be run on the furnaces at one particular voltage without shutting down. He complimented the Institute in having brought together a series of interesting papers on electric furnaces and should like a similar line to be taken in connection with other subjects.

Mr. D. F. Campbell said it would be interesting to the meeting to be informed that at the outbreak

of war in 1914, the country was in a bad situation in regard to tungsten and ferro-chrome. At the end of one week, thanks to the electric furnaces, ferro-chrome was being produced in large quantities, and tungsten also. Since then a very large output of ferro alloys had been arrived at. The present output of electric steel was 40 times that of 1914, this proportion not including the ferro-alloys, aluminiums, &c. The lack of Swedish iron had rapidly been overcome by the aid of the electric furnace. Tool steel produced direct in the electric furnace was equal to that obtained in crucibles provided care were taken. It was feared at one time that the expansion of the electric furnace might be hampered by the lack of electrode supplies, but that had been overcome also. The economics in the manufacture of ferro-alloys had been profoundly changed by the peace, and the question of economics would be the governing question in this respect in the future. He agreed with the last speaker in the matter of providing for the robust construction of the switchgear. In large works it might occur that the performance of the electric furnace was not found so good as in comparatively small works; this could be attributed to the fact that the crane facilities were better in smaller shops. In regard to power contracts, the power consumer and the supplier of power did not occasionally work so well together as might be required, and no advantage seemed to be given to the manufacturer who had a high load factor as compared with the one having a low load factor. In this respect, he would say, matters were better on the North-East Coast. He suggested that a system of contract should be arrived at, fixing a price per unit and allowing reductions on the basis of the load factor. He also advocated the regulation of a large number of furnaces by a master regulator by means of which full advantage was taken when the load on one became available. By improving the load factor and the conditions in which the power was consumed there would result reductions in costs.

Sir Robert Hadfield congratulated both Institutes for holding the joint session, from which he thought advantages would be derived. The chief point at the present time in the matter of the utilisation of electrical energy for steel smelting largely turned upon the cost of power, and there was going to be disappointments unless there obtained a reduction in the cost of the said energy. He referred to the report by Sir Dugald Clerk, which pointed out that a great deal had to be done yet in this country in this matter. During the war his firm had set to work and had utilised in the electric furnaces a vast amount of scrap, and he took the opportunity for thanking the Sheffield Corporation for the help they gave his firm as regards current supply. Here, Sir Robert read a letter he had received from Mr. Paul Girod, who regretted his inability to be present at the meeting. Mr. Girod stated that "in the splendid progress which had been made in the manufacture of steel in the electric furnace during the war, it was rather a pity to find that, with the exception of the Héroult furnace, all furnaces recently installed were 'new.' The merit of the new inventors certainly counted for something. The war, however, had thrown so much work on French industries and under such difficult circumstances, that all companies had been compelled to confine their activities and the use of their staffs to the working of their own factories. Consequently, all business connected with patent licences, interesting as they might be, had to be shelved. He, Mr. Girod, had increased his annual output of 15,000 tons of ingots to 60,000 tons, a figure all the more remarkable as it was obtained from furnaces working on cold charges, exclusively for the production of alloy steels for artillery, road vehicles and aircraft. His works at Ugine (Savoy) had purchased from outside all classes of steel used in the manufacture of ordinary shell, reserving their entire productive capacity for the manufacture of steel which could not be obtained in the open-hearth furnace with sufficient regularity in the matter of quality. The important development of the 'mixed' type of furnace, i.e., that in which the current passes through the hearth and the electrodes, would come out at the meeting. The number of patents taken out for furnaces of this type is already so considerable that, added Mr. Girod, it may perhaps not be out of place to state that as long ago as 1899 he designed a tipping furnace, having a conducting hearth, used for the making of alloy steels; whilst in 1905 he patented a furnace having embedded metal poles, which, unless he was mistaken, was really the prototype of all industrial furnaces having a conducting hearth. If we have to concede to Mr. Héroult, Mr. Girod further stated, absolute priority for the manufacture of steel on an industrial scale in the series arc double-electrode furnace, he (the writer) thought he could claim for himself priority for the opposite principle, which consisted not only in using the current at the surface of the bath, but in causing it to pass through the whole of the molten mass, and that with the longest possible travel, so as to secure great regularity and greater ease in regulating the operation of the furnace with cold charges. There were now working at Ugine a number of furnaces of 25-ton capacity on cold charge, these furnaces being capable of taking 30 tons of liquid charge quite easily." Sir Robert added that Mr. Girod had always been ready to supply to him full information in unlimited amount, this affording another proof of French cordiality. In conclusion, Sir Robert said the electric furnace was eminently good for the making of steel of high quality, but there was the question of cost of the necessary energy to be reckoned with, and he hoped the cost would be reduced.

Colonel David Carnegie said that Canada was placed in an awkward position at the commencement of the war. Canada sent scrap to the United States and bought steel from them. A Canadian firm then decided to put down furnaces for dealing with their scrap and installed the Héroult furnaces of the 6-ton type, ten in number, placed side by side; they hoped to get from the plant 300 tons of steel per day, but in a short time the capacity of the plant had reached 400 tons. Canada was now to the fore and produced steel in the electric furnace at the lowest cost, owing to the cheap power available. The fact should also be borne in mind that Canada had in abundance magnesite for the furnace linings, and also facilities for the making of carbon electrodes at a low rate. In regard to cost, the best open-hearth acid or basic steel could not be produced in Canada more cheaply than steel in the electric furnace. There were many ore beds in Canada, some of inferior quality. He had not read the papers then before the meeting, but would like to know whether the authors had anything fresh to say with regard to the possibility of making economically steel direct from the ore in the electric furnace. Experience in Canada in this respect had not been satisfactory, but he did not see why the difficulties surrounding the direct manufacture of steel should not be overcome. He hoped that for the ferro-alloys, which could not be made economically in this country, the Canadian manufacturers of such would be given the preference.

Mr. Walter Dixon expressed doubt as to whether the joint meeting would be a successful one after all. He did not see what was going to be the outcome of the proceedings. One point had come out and would be useful, and it was to the effect that the induction furnace was out of court; as to the remainder, the various types of furnaces were practically similar one to another. Before the war there were in this country one or two electric steel furnaces only, and there were now probably forty times as many. It was simply the war which brought this about, and the question of economy in no way entered into the matter. Economy, in fact, took a secondary place. One could not help feeling that electric furnace designers greatly exaggerated the bearing of the development which the electric furnace had had during the war. As for the blast furnace being replaced by the electric one, that was completely out of the question. In steel-making there was a tendency to endeavour to deal with larger quantities than was feasible. The electric furnace might come in for certain capacities up to probably 6 tons or 10 tons, and under conditions which were not subject to economy. The trouble now was that the electric furnace was being boomed, and that done under what he would style non-war conditions. "It was not there." As a secondary process the electric furnace would be good, but it was out of question in competition with the open-hearth furnace, for anything except fine steel of very special quality.

Mr. E. H. Janiter said he had not had much experience in the working of the electric furnace, but he felt sure that the manufacture of electric steel in competition with open-hearth steel did not stand the ghost of a chance. The acid open-hearth furnace could produce the finer steels equally well and more cheaply. In tests, he had not found that electric steel was in any way superior to open-hearth steel. For certain classes of tool steel there would be a future for the electric furnace. In the matter of testing, the same number of tests were made during the war on the output of 2 tons to 5 tons of an electric furnace as in the 25 or more tons output of an open-hearth furnace, and this resulted in considerable inconvenience.

Mr. E. Adamson found that the meeting had, on the part of the electrical engineers, developed in the technical consideration of matters of detail, and he did not think it would result in guiding the users of electric furnaces. It was obvious, as other speakers had said, that the electric furnace was serviceable for certain classes of steel only. It would come in for the higher grades; the material used in the furnace would decide the point. In this country the cost of power was a most important factor, and it came in in regard to the production of pig iron electrically more than it did in the production of electric steel, the waste heat had not been turned to account to any great extent in the case of the electric furnace.

Mr. H. M. Ridge said that in his experience it was astonishing how several furnaces had been constructed. In electric furnaces it was not only the electrical engineer and the metallurgist who came in, but also the constructor of the furnace; what he would call the constructional element had been rather lacking. Co-operation among the three would assist progress, better results and longer life for the furnace would be ensured.

Mr. H. H. Ashdown endorsed Mr. Saniter's remarks, and said that the electric furnace did not have the monopoly in the production of the best steel; the utmost care had to be given to the electric furnace in order to obtain with it the best results. From a note contained in ENGINEERING of April 25, one could see the difficulties met with in America in regard to nickel, and nickel-chrome steels. This applied also to tool steels. There was a limit to the capacity of an electric furnace, and he repeated that in order to obtain with it the best possible results the greatest care had to be given to the working of the heat.

Mr. W. M. Mordey questioned whether the electrical engineers and the steelmakers were not rather hard in asking for a reduction in the cost of electrical energy, seeing that there had been losses in energy in the electric furnace in every direction. Some time ago 1,000 units were required per ton; now steel was smelted at a consumption of 560 units to 570 units per ton, and it had been stated that in Canada the consumption of current had gone down to still lower figures. There was also great economy obtainable in the expenditure for electrodes. During the war these had cost 10s. to 20s. per ton of steel. There might be more profit in the making of electrodes or in the building of furnaces than in the manufacture of steel. Great saving in energy was possible by carefully inspecting the electric furnace and applying common sense to the working. In looking into a furnace one could see the energy flying away all the time. The carbon electrode burned to a point; luting could be resorted to, but the luting, if not looked after, gave a path for the flame to fly up along the electrode. Mr. Stobie had adopted a means for correcting that. The success of the electric furnace during the war was mainly due to the availability of swarf; this was shovelled into the furnace instead of being thrown away as formerly, and the experience gained in that connection was of very great value indeed. He asked whether the induction furnace was really dead. From the electrical point of view it had many interesting features, and it would be interesting to hear from those who had had experience both with the induction and the arc furnace, what had led to the abandonment of the former. Few knew

why it had failed. It had a large area of hearth and a large area for leakage; it had also an unpleasant disease called the pinch effect, but a designer had proposed to turn to account that effect to concentrate the heat. The heat leakage was probably great, but there were no flames and no electrodes; it had the advantage that the heat was produced where it was wanted, namely, in the metal itself.

Mr. Parker said that he had tried the Kjellin furnace, but had abandoned it.

Mr. Brown thought that the Iron and Steel Institute members and the members of the Institution of Electrical Engineers were, perhaps, not showing sufficient confidence in each other. Mr. Saniter had said that acid open-hearth steel could be produced more cheaply than steel in the electric furnace, but the question might be asked how much longer would the manufacture of acid steel be continued; basic steel was being produced more and more as time went on. As far as ordinary steel was concerned the electric furnace would be used as a means for refining. Nothing had been brought out in the discussion as to the American triplex process, in which that furnace formed the last link. At a high current price it was difficult for the electric furnace to be a commercial success, and he asked that the price of current should be brought down a farthing per unit, or even less.

Mr. H. B. Toy stated that as he had had trouble with his hematite, he had put down two electric furnaces, in which he melted down steel trimmings. He was perfectly satisfied with their working for special alloy steels. He complained, however, at the price charged for current, also at that charged by the so-called makers of electric furnaces for royalties, and thought that during the period of war the designers were not entitled to the high royalties they demanded.

Mr. W. J. Dawson said that one point for consideration was as to whether a higher voltage was not to be desired in furnace equipment. The diameter of the electrodes, he thought, could be reduced and thus increase the life of the furnace roof. A quicker input avoided radiation losses. Electric economisers, if they were durable, would be an advantage, as all steelmakers realised, but they never seemed to work long.

Sir Robert Hadfield further stated that the electric unit was paid at the start for melting steel ·6*d.*, then ·7*d.*; the price was now ·8*d.*, and would very likely soon be 1*d.* This country had to face the competition of the whole world, and electric energy had to be supplied more cheaply. He hoped metallurgists would be helped in this respect, and not only in regard to the use of that energy for melting purposes. A question that might be asked in this connection was as to whether the heat conveyed by electric energy was of the same nature as that due to combustion. There must certainly be some difference in the effect upon the molecules of the steel. He recalled Lord Chetwynd's process, which consisted in the application of an electric current to the liquid steel in the ladle during a period which varied from 20 min. to 40 min., Lord Chetwynd claiming that by this means he got rid of a large number of the inclusions in the steel. He (Sir Robert) did not see any difference, but it might be that the current had an effect on the steel, although it was difficult to understand what that effect was.

Mr. G. M. Partridge, speaking as a supplier of electric current, emphasised the effect of the load factor, and said that before the war, current in London was offering at below ½*d.* per unit for furnaces. If, now the war was over, the power engineers were allowed to breathe and were supplied with economical plant the price would go below ½*d.* per unit. The cost of coal to power supply firms would, perhaps, be reduced, but he did not think there was much chance of the cost of labour falling. It had been stated that rates to users should be made to vary according to the load factor. He (the speaker) agreed, and was surprised that a user having a high load factor was not quoted a lower scale. Owing to the large subdivisions for current supply throughout the country, any large firm coming into a system might have for effect to disarrange that system; but when the main current supply was to a railway, for example, when the firm came in, there was no difficulty. The suppliers of current, he assured the meeting, would always endeavour to give a cheap supply. On the other hand, the furnace designers should continue to work for improving the consumption per ton at the furnace.

Mr. D. Sillars said the manufacture of pig iron and the smelting of steel were two entirely different propositions, and in this country, at all events, the manufacture of pig-iron by electric power obtained from coal was out of question. He did not think, moreover, that electric furnaces of large size would be successful, owing to the difficulty of applying the heat all over the bath. If the roof of the furnace were pierced so as to take, probably, six electrodes, the result would be a very weak roof; the bottom of the furnace would also be weakened by reason of the presence of a correspondingly large number of bottom electrodes.

Professor Louis said that before the war current was offered to him in Norway at a battery of electric furnaces at the price of 27 kr. (30*s.*) per kilowatt year for very large quantities. The question, therefore, resolved itself in the cost of power as produced.

Mr. A. P. Pyne stated he was struck by the very great difference in cost of production between different furnaces, and thought this was attributable to management. He was a great believer in the automatic control of furnaces. All transformers should be so built that they can be repaired at the site and throw the furnace idle for a minimum length of time. This difficulty was obviated by the provision of spare transformers, but these involved a higher expenditure.

Mr. T. M. Service, who followed, said he had had experience with a small electric furnace used for the making of nickel-chromium steel. He had cut up ingots so made, and had found that they were superior to others made in the acid open-hearth furnace. But, he added, this might be due to the fact that they were of small size. He, therefore, arranged for a trial made in one of the largest electric furnaces of the country. The charge consisted of armour plate scrap which was melted down. From the ingots derived from the two charges of nickelchromium steel he thus obtained, hollow forgings were made, showing a yield of 40 tons, and an ultimate stress of 53 tons per square inch, and correspondingly excellent impact tests. The report from the clients stated that the forgings in question were the best they ever had, and he was asked to make a specialty of the manufacture of electric steel.

Major Taylor, who closed the discussion, said it seemed practicable to supply a single-phase furnace on a three-phase system of mains, by superposing the single-phase on the three-phase system. One could thus supply, say, 1,000 volts on a system of 4,000 volts between the outers without disturbing the existing customers on the mains. He had gone into the actual running cost of power, and his figures for pre-war times showed the actual true running charge to have been ·8*d.* per unit. At night time the cost would probably be one farthing per unit. He asked the steelmakers to endeavour to make their load regular and continuous throughout the year, which would facilitate a lowering in the price. There was no need whatever for any discouragement, and the electric engineers had not reached the end of their resources.

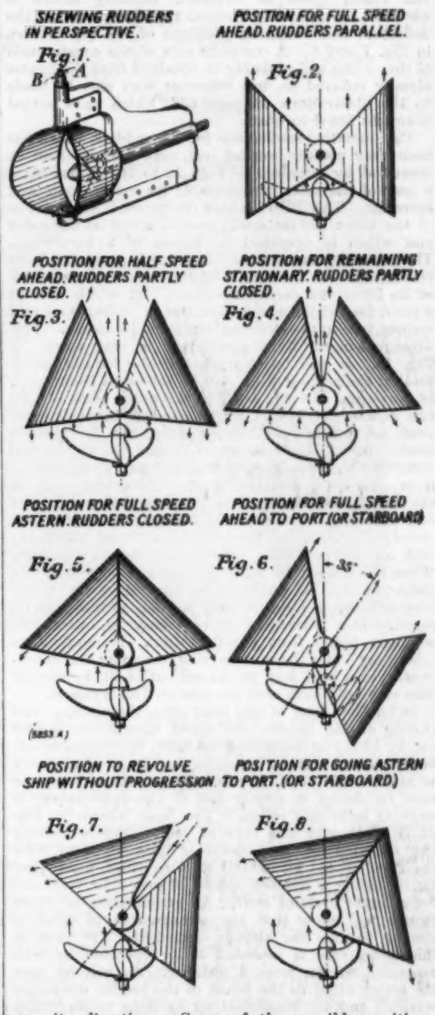
The Chairman announced that the authors would deal with the discussion by correspondence, and conveyed to them the thanks of the meeting for their contributions.

(To be continued.)

THE KITCHEN REVERSING RUDDER.

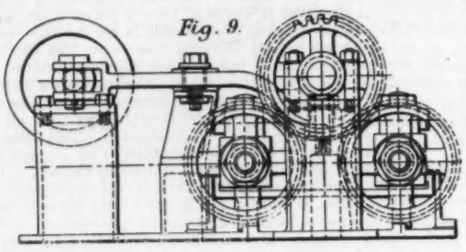
On the present page and pages 632 and 633 we illustrate a new form of ship's rudder which is of very considerable interest. The rudder, which is the invention of Mr. J. G. A. Kitchen of Lancaster, has been in use for several years, but considerations arising out of the war have prevented, up to the present, either its proper commercial development, or publication of particulars relating to it. The rudder belongs to the class of simple and effective devices which, once they have been applied, immediately give rise to wonder why the application had not been made years before. The whole arrangement, apart from the operating gear, which is simply a question of mechanical design, is shown in Fig. 1, and the simple construction there shown is sufficient to enable a boat to be steered, reversed, controlled in speed and manœuvred in any way from a single tiller, with the engines running continuously in the forward direction. The advantages of being able to do this will vary in different cases, but without enlarging on the matter at the moment it is clear that complete and direct control from the bridge over all movements during manœuvring is obtained and further that all engine reversing gear may be eliminated. This latter point is of direct and immediate interest in connection with craft driven by internal-combustion engines.

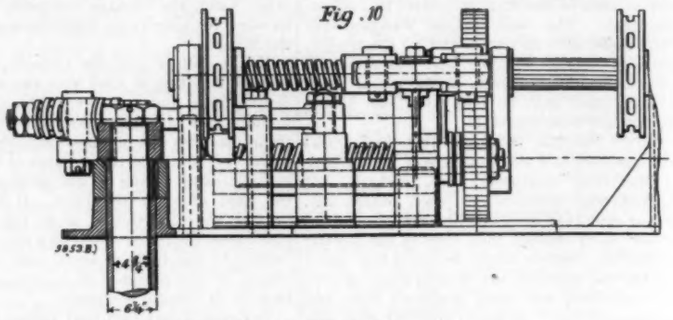
Before dealing further with the application of the rudder, it will be well to say a little more in detail in reference to its construction. As shown in Fig. 1, it consists of two curved deflectors forming parts of a circular cylinder and partly enclosing the propeller. The deflectors are pivotted at the top and bottom on common centres, and are capable of being swung together in the same direction, or equally in



opposite directions. Some of the possible positions of the two deflectors are shown in Figs. 2 to 8. One deflector is operated by the solid shaft A and the other by the hollow shaft B, through which A passes, as shown in Fig. 1. In ordinary running ahead the rudder would be as shown in Fig. 2, the deflectors standing fully open and entraining the propeller race. Steering is carried out as with an ordinary rudder, the two deflectors moving together into the position, for example, shown in Fig. 6. Speed control is achieved by altering the angle between the deflectors. When they are partially closed, as shown in Fig. 3, part of the stream of water coming from the propeller escapes between the deflectors and still drives the boat forward, but part is deflected forwards and tends to have the opposite effect, with the result that the boat is slowed up, although the engine speed is unaltered. By further closing the rudder, as shown in Fig. 4, a position is reached in which the two re-actions balance and the

OPERATING GEARS FOR THE KITCHEN REVERSING RUDDER.





boat remains stationary. By completely closing the rudder, as shown in Fig. 5, the whole propeller stream is deflected forwards and the boat moves astern. In general an astern speed about one-third of the full ahead speed is obtained. Steering astern is obtained by combining the two types of motion of the deflectors and obtaining positions of the type shown in Fig. 7 and 8. A complete idea of the construction of the rudder will probably be obtained from the figures already referred to, but reference may also be made to the illustrations on page 633, which show actual examples fitted to boats.

The operating mechanism for the rudders, which has been very prettily worked out, may perhaps best be described by reference to Figs. 12 to 16. These show a gear of the tiller type suitable for motor boats and launches. The tiller, which is pivoted at the top of the outer rudder stock, carries a nut at the outer end which is operated by means of a handwheel. The nut can rotate on the tiller, but is prevented from traversing. In the nut a leading-screw works which at its inner end carries a vertical bolt which acts as a pivot for two links which connect up to levers secured respectively to the inner and outer rudder stocks. This arrangement of links and levers is best shown in Fig. 13. It will be clear that if the hand-wheel is rotated the leading screw will be traversed backwards, or forwards, carrying with it the outer ends of the two connecting links. By this means the two lever arms are rotated together, equally, but in opposite directions. As these levers are connected to the two deflectors of the rudder by means of the rudder stocks, it is clear that rotation of the hand-wheel controls the opening and closing of the rudder and thus the speed and reversing of the boat. Steering is carried out merely by swinging the tiller as a whole exactly as with an ordinary tiller fitted to an ordinary rudder. When this is done the relative position of the two rudder deflectors has no tendency to alter since the whole arrangement is rigid in any position of the leading screw. This tiller gear is very easy to operate as we have found from practical trial. It requires no "learning" and the manœuvring, reversing and speed-control of a boat may be carried out easily by anyone who may only have seen the gear on first trying it.

In another form of this tiller gear, the opening and closing of the rudder—the speed control—is carried out by lifting or depressing the tiller, steering as before being carried out by swinging it. It is unnecessary to say more in detail of this arrangement as it is clear that its design is merely one of the applications of suitable links and levers. The boat shown in Fig. 23 is fitted with this type of gear. Before leaving the question of the operating gear we must refer to Figs. 9 to 11, which show a tiller head gear for operating a Kitchen rudder of a heavier type and for a larger class of boat. An examination of these figures will show that the arrangement in effect is similar to the one already described. The gear in this latter case is intended to be operated by wire ropes, or chains, from a distance. As will be seen the levers fitted to the heads of the rudder stocks are retained and are connected up by links to traversing nuts working on right and left-handed leading screws. These screws are rotated by gearing from the operating pulley and it is clear that the rotation of this pulley traverses the nuts equally in opposite directions and swing the rudder as a whole to port or starboard. The opening and closing of the rudder to obtain speed control, and reversing is obtained by moving the leading screws with their gearing bodily as a whole. This clearly swings the rudder stock lever arms in opposite directions and opens or closes the rudder deflectors. To enable this action to be carried out the leading screws and their gear are mounted on a sliding carriage which is able to move along the main bed plate. The position of this sliding carriage is determined by a rocking lever, which is operated by a third leading screw which can best be seen at the bottom of Fig. 11. This leading screw is moved to and fro by a nut carried by the chain or wire-rope operated control pulley. It will be seen that the two driving pulleys are fixed

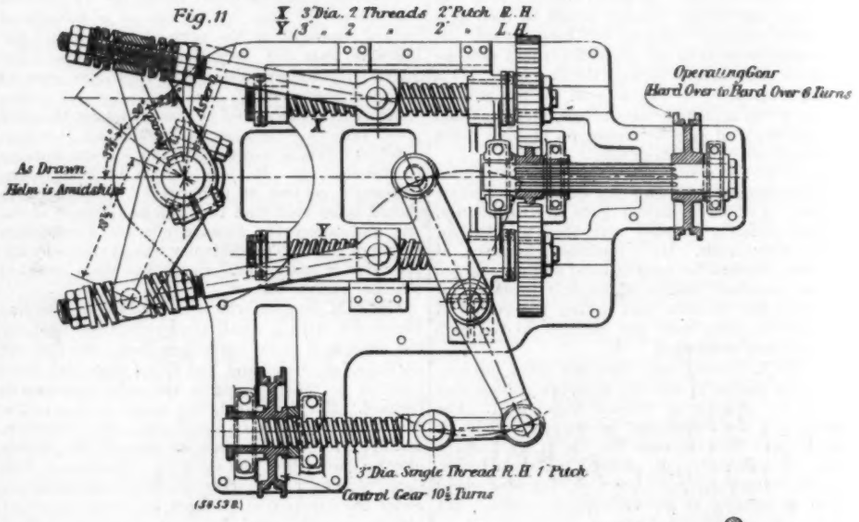
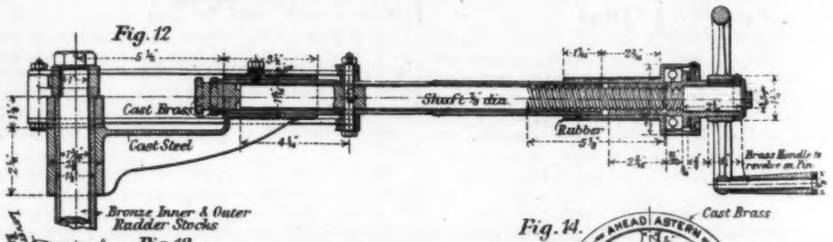
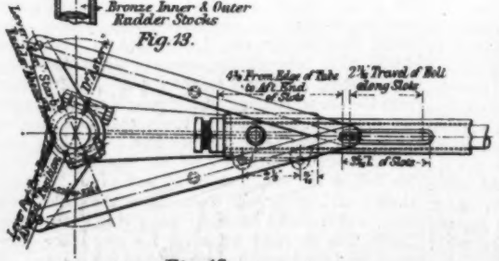
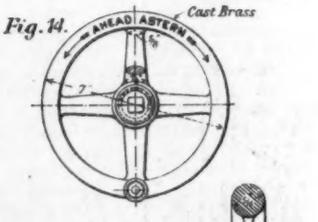
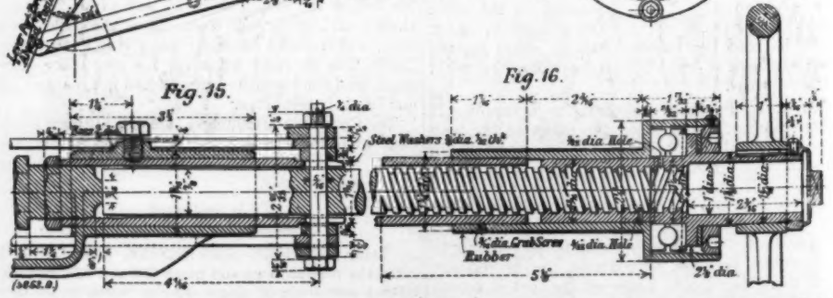


Fig. 11.
X 3" Dia. 2 Threads 2" Pitch R.H.
Y 3" " 2 " 2" " L.H.
Operating Gear
Hard Over to Hard Over 6 Turns
As Drawn
Helm is Amidships
3" Dia. Single Thread R.H. 1" Pitch
Control Gear 10½ Turns





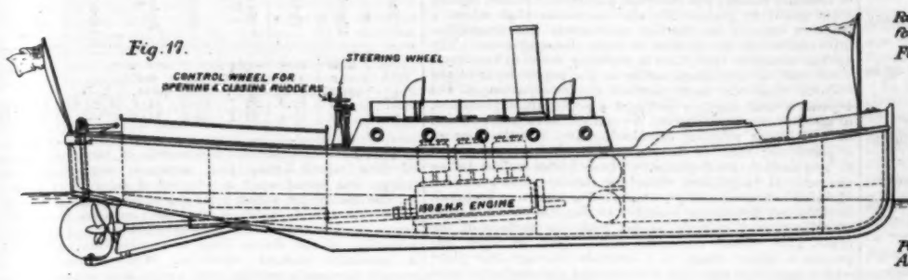


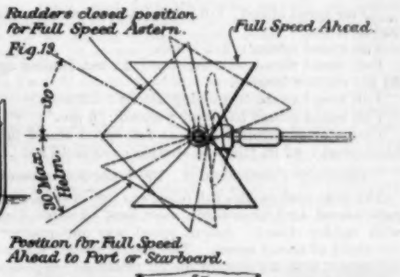


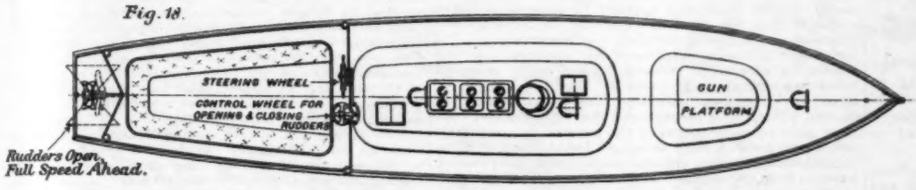
points, the pinion on the steering pulley spindle sliding along the spindle as the sliding carriage moves backwards and forwards. Fig. 22 shows a further type of arrangement, in which the control and steering wheels are mounted independent of each other.

Up to the present the Kitchen rudder has been fitted to a number of motor boats, Admiralty pinnacles, &c., driven by oil engines. Figs. 17 to 20 show the arrangement as fitted to a 50 ft., 150 B.H.P. Admiralty pinnace. It is in connection with such craft that the advantages of the rudder are most immediately apparent, in that it enables reversing gear to be dispensed with. The rudder is, of course, much simpler than a reversing clutch, feathering propeller, or other of the devices which have been used to enable a motor boat to reverse. Naturally to make a place for itself the rudder must prove itself reliable, and in this direction it has a good record, no case of failure having occurred during its several years of trial. There is, of course, nothing in the construction

APPLICATIONS OF THE KITCHEN REVERSING RUDDER.




Rudders closed position for Full Speed Astern.
Full Speed Ahead.
Fig. 19.
30°
30° Max. Helm.
Position for Full Speed Ahead to Port or Starboard.



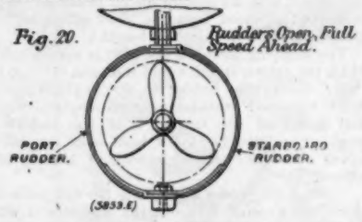


FIG. 21.

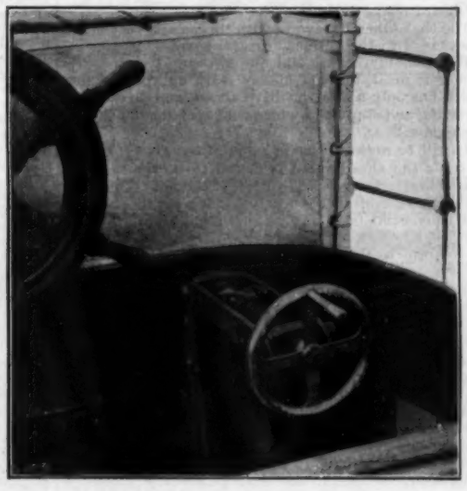


FIG. 22.

FIG. 23.

of the rudder to make one anticipate failure. It is, however, not merely as a substitute for reversing clutches and similar devices that the introducers of the Kitchen rudder are hoping it may prove of service. The flexibility of control and rapid manœuvring qualities which the rudder gives are of importance in cases in which reversing in an ordinary way presents a difficulty. The control exercised by the rudder over the boat is so effective that a 25 ft. motor boat can be turned on her own axis through 180 deg. in 20 seconds, while the reversing action is so powerful that its effect may almost be described as instantaneous.

We have had an opportunity of witnessing some trials of two motor boats fitted with the rudders, and were greatly struck with the manœuvring power exhibited. The steering control was very powerful and rapid in action, while the reversing power was remarkable. One of the boats, 25 ft. long, running at 10 knots, was pulled up as though she had run into a mud bank. This rapid reversing is probably due to the fact that the propeller does not reverse, and consequently continues to operate in solid water. At the moment of reverse there was apparently no strain on the ship's structure. This is to be expected, as the conditions inside the boat do not change. Any strain which comes into play must be taken by the rudder, and this raises the question of the ability of the rudder to stand the work thrown on to it. Although the rudder may be moved over from full-speed ahead to full-speed astern as quickly as the helmsman is able to do it, there is none the less no sudden shock on the deflectors, which take a measurable time to close, so that the water is deflected gradually from a full stream astern to a full stream ahead. A further point is that the shape of the deflectors in itself gives considerable strength. The best reference on this question of mechanical strength of the rudder is, however, to practice, and during several years' experience with instant reversing and complicated manœuvring of every type there is no record of a rudder failure.

Records of various official trials of boats fitted with a Kitchen rudder are given below :—

"*Pinnace, 20 ft., 7 brake horse-power (Admiralty, 1919)*

Ahead speed : 6·2 knots (same as with ordinary rudder).

Astern speed : 2·02 knots (propeller full speed ahead).

Full speed ahead to moving astern : 7 sec.

Full speed ahead to dead stop : 4 sec (in less than half boat's length).

Full speed astern to moving ahead : 4 sec.

Diameter of turning circle at full speed ahead (helm hard over) : About one length of boat."

"*Launch, 25 ft., 16 brake horse-power (Air Ministry, 1918).*

Ahead speed : 9·80 knots.

Astern speed : 3·5 knots.

Full speed ahead to dead stop : Boat pulled up in 23 ft. (four men aboard).

Full speed ahead to dead stop : Boat pulled up in 16 ft. (one man aboard).

Time taken turning complete circle on own axis

without progression in any direction: To starboard 33 sec., to port 26 sec."

Motor Boat, 35 ft.

"Full speed ahead: 7·6 knots (same as with ordinary rudder).

Full speed astern: 2·2 knots.

Full speed ahead to dead stop: 12 sec. (pulled up in 35 ft., its own length).

Full speed ahead to moving astern: 15 sec.

Full speed astern to moving ahead: 6 sec.

Diameter of turning circle at full speed ahead (helm hard over): 42 ft. (time to complete circle 43 sec.)."

"Admiralty Pinnace, 50 ft., 150 brake horse-power.

The boat with rudder full open was run over measured mile ahead and afterwards over part of same course with rudder closed. Astern speed was one-quarter to one-third of ahead speed. The astern speed, although not great, is quite enough for all practical purposes.

From full speed ahead to dead stop the boat was pulled up in 50 ft. (her own length).

The stopping power of the boat is very much greater than the astern speed would indicate.

By closing the rudder to the neutral position the boat remained stationary (with engines running at full speed all the time). With the rudder in this position and the helm put hard over she described a circle about her own axis without moving ahead or astern.

Closing the rudder and giving her full helm the boat described a complete circle, the diameter of which was 75 ft., and the time taken 70 sec. and 74 sec., port and starboard respectively.

The time taken to reverse with this gear is very much less than with the ordinary reverse gear.

For manœuvring in and out of confined spaces the rudder is ideal, for you merely start up your engine, which has only a straight drive ahead, and do all your reversing and stopping by means of opening and closing the rudder."

It will be noticed that in some of the above records of trials the ahead speed is stated to be the same as that obtained with an ordinary rudder. This has been the case in all boats which have been equipped. We believe no boat has yet been built purposely to carry a Kitchen rudder. As the rudder can be made to conform to the streamline flow of the water aft, it is possible that such a boat might show a slight improvement in speed over a similar boat fitted with an ordinary rudder. The question of the fitting of the Kitchen rudder to a large class of boat is now under consideration. It is quite possible that even in steam vessels with ordinary reversing gear the speed and flexibility of manœuvring obtainable with the rudder will make it worth while fitting it for use during docking and similar operations. Nothing has yet been done, we think, in connection with twin-screw boats, but we understand that in such cases the rudder deflectors would be built to embrace both propellers. In conclusion, we should say that inquiries in reference to the rudder should at present be addressed to Mr. Gordon H. Fraser, of 747, Royal Liver Buildings, Liverpool. A company is, we understand, being formed to work the patent in the United Kingdom, and the rudder will shortly be available for all requirements. Further, we should thank Mr. Fraser, Mr. Kitchen and others connected with the matter for courtesy extended to us during our visit to inspect the application of the rudder.

THE MECHANICAL PROPERTIES OF STEEL.

*The Mechanical Properties of Steel, with Some Consideration of the Question of Brittleness.**

By W. H. HATFIELD, D.Met., of the Brown-Firth Research Laboratory, Sheffield, Associate Member.

(*Continued from page 618.*)

True Brittleness.—In the first place it is useful to ask—Are steels prone to occur in a truly brittle condition? To this question there can only be one answer—Yes. Evidence of this has been presented. Stead, and also Sauveur, have also described undoubted instances, particularly with low-carbon rolled steel. Continental workers have also produced evidence of a similar order. To arrive at cases of true intrinsic brittleness, however, it is necessary to eliminate a very much greater number of cases of "apparent" brittleness. As to what produces true brittleness, the author considers that the explanation must be looked for in the effect which the final treatment and experiences have upon the crystalline structure of the iron matrix of the steel. With true brittleness the crystalline arrangement within or between the crystals must be very different to that occurring in materials in the normal tough condition. It is also evident that certain steels under like conditions of treatment develop intrinsic differences more readily than others, but it is claimed by the author that true brittleness is readily discovered in the mechanical testing laboratory, and shows itself in the tensile and other values obtained.

* Paper read before the Institution of Mechanical Engineers, on Friday, May 2, 1919.

Sauveur * has described what he calls cleavage brittleness as being caused by the ferrite grains assuming nearly the same crystalline orientation, so that a plane of fracture follows the cleavage planes and passes readily from grain to grain. He also considers that where a fracture cannot be readily developed, the crystalline orientation of the grains is more heterogenous. The author considers that there is probably much in Sauveur's view, and, as explained earlier in the paper, he is of the opinion that the more perfect the orientation of the crystal within itself is perhaps a sufficient explanation of notched-bar brittleness. We cannot leave this question of brittleness without mentioning Dr. Stead's view of a particular kind of brittleness, which he has studied in low-carbon steel plates. These plates rolled below the critical range, and therefore strained and annealed likewise below the range, exhibited a tendency to break in different directions, namely, 45 deg. to the direction of rolling, and at right angles with the surface of the plate. Dr. Stead considers that "just as light impresses a latent image on a bromide photographic plate which cannot be seen, but is developed and made manifest by the action of certain chemical changes, so the rolling under certain conditions appears to impress a latent disposition in the steel to crystallise in certain fixed positions and annealing develops it afterwards."

Sauveur in commenting upon this considers that the crystalline growth of strained ferrite, when annealed below its critical range resulting in the formation of large ferrite grains, naturally caused brittleness. It should, however, be remembered that Osmond and Cartaud have actually examined the mechanical properties of iron crystals of large sizes and found them to have considerable ductility, and one would judge comparative freedom from brittleness. Much further data is desirable concerning the physical and mechanical properties of different individual crystals, and it is to be hoped that more will be forthcoming in this direction during the next few years; such data cannot but have a very helpful influence on our ideas concerning this subject.

True brittleness must be dissociated from notched-bar "brittleness," since non-brittle steels give identical values to steels which have hitherto been considered brittle under notched-bar tests, but which obviously from many standpoints cannot be so considered. The appearance of fractures, that is, crystalline or fibrous, has always had much weight in determining whether steel is brittle or non-brittle. Such appearances are useful indications, providing the magnitude and the manner of application of the force which produces the rupture is completely or sufficiently under control. The material in tough and notch brittle conditions respectively will break with fibrous fractures in tension, whilst under a notched-bar test the former will have a fibrous and the latter a crystalline fracture. Again, one may smash a large section of steel, and one portion of the fracture will be fibrous and other portions crystalline; if Izod impact-test are taken from the unlike area, identical absorptions of energy in breaking will most likely be obtained. Tough materials, breaking through local concentrations of stress in the vicinity of primary cracks or defects, frequently present sharply crystalline and apparently brittle fractures.

The Elastic Range.—The definite deduction to be drawn from all endurance tests is that the elastic range is the fundamental factor that must be studied. In the author's opinion the incompleteness of our knowledge concerning the truly elastic range is one of the disabilities under which we are at present working in engineering design. From the engineer's point of view it is not satisfactory to know that a piece of steel will break under a certain number of alternations or repetitions of stress. What he really desires to know is the nature and magnitude of the stresses which the steel will bear in any part under consideration for an indefinite, one might say infinite, period of time. In the first place he must complete his knowledge concerning the elastic properties of the steel, and in the second place he must complete his knowledge of the actual stresses which the part has to bear. A very considerable amount of work will have to be done in both directions before engineering design is capable of simple mathematical treatment. In this connection a few words with regard to steels may be of interest.

The author recently had before him two German turbine discs made of carbon steel. The analyses were as follows:—

	A. Per cent.	B. Per Cent.
Carbon	0·30	0·24
Manganese	0·93	1·05
Silicon	0·20	0·20
Sulphur	0·06	0·05
Phosphorus	0·034	0·050
Nickel	Nil.	Nil.
Chromium	Nil.	Nil.
Tungsten	Nil.	Nil.
Vanadium	Nil.	Nil.

These analyses are of interest in so far as the manganese will be found to be on the high side. The microstructures will also be of interest. Fig. 8, page 635, represents the disc in longitudinal section, at 100 diameters and 500 diameters etched. Fig. 9 represents the disc in transverse section, at 100 diameters and 500 diameters etched. The structures will be seen to be normal structures for the composition, but it will be noted that the non-metallic inclusions (sulphide, slag, &c.) are well segregated and present to a rather unpleasant degree. The mechanical properties of the two discs were carefully determined, with the results shown in the following table:—

Sample.	Elastic Limit.	Yield-Point.	Maximum Stress.	Elongation.	Reduction of Area.	Izod Impact.	Brinell Impact Number.	
	tons per sq. in.	tons per sq. in.	tons per sq. in.	per cent.	per cent.	ft.-lb.		
A.	7·1	12·7	32·7	28·0	44·8	34, 22, 25	5·05	140
B.	7·8	13·4	31·3	34·5	51·4	—	4·80	156

This data is given in illustration of the possibilities of low elastic-limit. For instance, supposing that design was based upon a "factor of safety" of 4 to 1 on the maximum stress tons per square inch, it will be clear that in the instance of these two discs the elastic range would have been slightly exceeded. The determination of the elastic limit is troublesome and needs a carefully trained observer. Whilst, however, it cannot become a routine test, yet it does appear to the author necessary that the engineer should take more interest in it than he has hitherto done. In steels of comparatively similar mechanical properties there may be considerable difference in the range of proportionality, and how wide the difference may be is clear to all investigators who have given much attention to this side of the subject. It will be clear that the turbine discs, particulars of which have just been given, were not capable of carrying high stresses.

The author has always assumed, and will continue to do so until experimental evidence is brought forward to the contrary, that the elastic range (except in cold-worked materials) is coincident with the range of proportionality, that is, it is coincident with that range of stress where strain is proportional to stress. There is rather a feeling now that the truly elastic range may continue somewhat beyond this range of proportionality, and it is in this direction that a good deal of useful work can be done.

At this stage it will perhaps be useful to discuss as completely as possible the mechanical properties of different steels when tested by the different tests available.

The Mechanical Properties of Steels Used for Different Purposes.—The author has now, for some time past, made careful investigations into the actual values to be obtained from steels which have given good service under varying conditions. It is proposed to present a few examples. In considering such figures one has always to bear in mind that the engineer, in determining the design and strength of the part in question, was guided by his experience and knowledge to date. It does not follow that with continued evolution in our knowledge of the material and of the distribution of stress of the different parts during working conditions, that the effectiveness cannot be improved upon, and it does not follow that the values obtained in a successful part are the most effective values which can be introduced. Such determinations do, however, definitely enable us to eliminate causes of failure in other parts similarly designed and constructed of like material. It is only by considering in detail such good examples that it may be determined in what direction suitable improvements can be introduced. It has always appeared to the author that it would be most unfortunate if particular ideas became axioms before being experimentally established, and it is thought that great care should be taken not to assign to the results obtained from useful methods of investigation an importance which they do not possess.

In Table II (page 635) will be found the results of a relatively complete mechanical examination of eleven different steels. In each case the material is in a state in which it has successfully met the demands which working conditions made upon it. In no case is it claimed that the material is in its most perfect condition, but the values produced by the different methods of mechanical testing give useful data. The relationship existing between the different values in a given condition of a particular steel are well brought out incidentally, some indication is given of the mechanical properties associated with steels and conditions of steels which long experience has determined to be best suited for certain purposes. The author has examined many steels in this manner, and considers that much more such work should be done if we are to correlate suitably the full mechanical properties of steels with their behaviour in service.

With regard to springs for railway or motor transport, there is a direction where considerable elastic deformation, reversal of stress, including shock, have to be withstood for an indefinite period. Experience has resulted in quite a hard condition of steel being employed, a high maximum stress, yield, and elastic limit with relatively little ductility. The author recently elicited the fact that the motor-springs produced by one of the best manufacturers of cars had an impact value * averaging 5 ft.-lb. under the Izod standard test. The author has examined different examples and is able to confirm that low impact values are quite ordinary. The essential feature in the spring is that it should have a wide elastic range. In Table II will be found the mechanical properties which have permitted springs to reach an extremely long life unimpaired.

As to tyres, it is found that complete success is attained by using a somewhat high-carbon steel, that is, with a pearlite matrix. This results in a relatively high maximum stress with a correspondingly wide elastic range. The elastic range would appear to be fundamentally important. In Table II will be found a full complement of the results on tyre material from other

* "Metallography of Iron and Steel." Sauveur, 1912.

* Hoblin. Inst. of Auto. Eng., 1918.

forms of test. One interesting feature is the response which it makes to the notched-bar impact-tests. The most excellent tyres which have proved to be extremely efficient in service, have, under the notched-bar test, a low notched impact value. The drop-test is employed in passing tyres, and it occasionally happens in different works that a tyre will fail under this test. It is common knowledge that in several works impact-tests have been performed on tyres which have broken under the drop-test, and tyres which have not broken under that test, and the astonishing fact is revealed that the tyres which failed had a higher notched impact value than those which withstood the test. The author always considers that a tyre travelling on a train at 60 m.p.h., jumping as it frequently does, from rail to rail, is a very sorely tried part. The complete investigation into the actual stresses which such tyres have to put up with under normal conditions would be worth attempting with a view to correlating the values obtained with the complete mechanical properties of the material.

To come now to propeller-shafts, turbine-shafts, and driving shafts of large dimensions. In Table II the full mechanical properties of a propeller-shaft of considerable dimensions are stated. Like values are typical of such large parts when made in carbon-steel. Alloy steels, such as nickel-chrome steel which demand suitable heat treatment, are apparently out of the question owing to commercial considerations. The result is that the engineer must accept the mechanical properties coincident with the type of material available for his purpose. Such shafts have the usual ferrite and pearlite structure, with the ferrite as the predominating constituent. This type of material has a maximum stress in the neighbourhood of 30 tons high ductility, but a low elastic range. Suffice it, however, that the engineer, knowing his material, constructs a shaft which satisfactorily performs the duties assigned to it.

Again in structural steel, examples of which are given in the same table, there are similar properties, although its thinner sections result in higher elastic ranges, owing to the quicker cooling. However, in considering such parts as shafts and structural items, the modulus of elasticity of the material is a serious feature, since the question of rigidity is important. Under a given load there is the same elastic deformation in high as in low tensile steels, and frequently the amount of elastic deformation is so important that for this purpose it does not pay to introduce high tensile steels. High tension material to be economically used would necessitate the employment of the thinner sections.

In Table II examples of the mechanical properties to be obtained from nickel-chrome steels are stated, and the advantage of employing alloy steels will be thereby definitely indicated. If the tests taken from the large mass of nickel-chrome steel are compared with the large mass, say, of the propeller shaft, superior mechanical properties are at once obvious. It is thought that if engineers would continue their present interest in the possibility offered by the important steels now available, many advantageous modifications in design would be introduced.

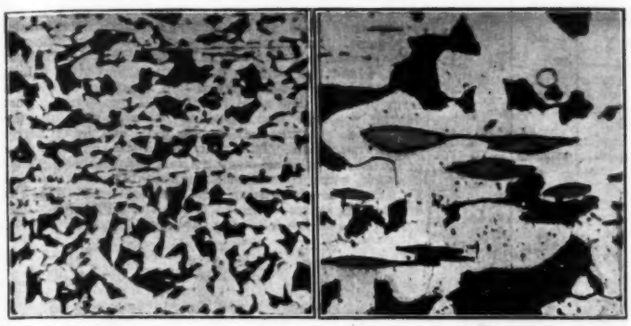


FIG. 8. TURBINE DISC (LONGITUDINAL SECTION).
× 100 DIAM. (ETCHED.) × 500 DIAM.

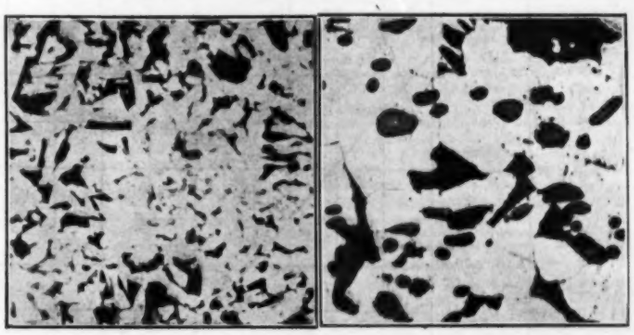


FIG. 9. TURBINE DISC (TRANSVERSE SECTION).
× 100 DIAM. (ETCHED.) × 500 DIAM.

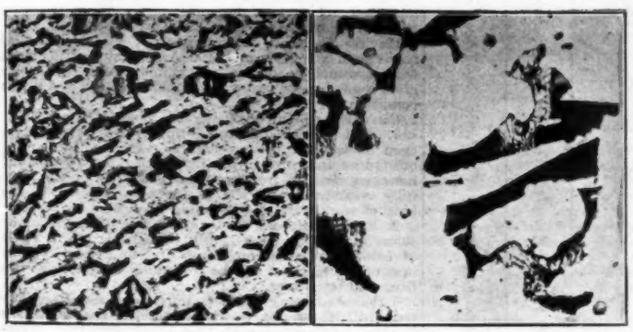


FIG. 10. STRUCTURAL STEEL (MILD).
× 100 DIAM. (ETCHED.) × 500 DIAM.

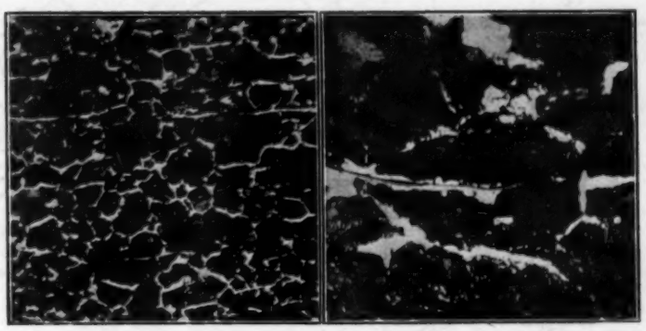


FIG. 11. STRUCTURAL STEEL (SHELL DISCARD).
× 100 DIAM. (ETCHED.) × 500 DIAM.

TABLE II.—MECHANICAL EXAMINATION OF 11 DIFFERENT STEELS.

Tests.	Structural Steel. (a) Ordinary.	Structural Steel. (b) Shell Discard.	Spring Steel.	Propeller Shaft.	Tyres.	Large Mass Treated Nickel-Chrome.	Very Large Heat-Mass Treated Nickel-Chrome.	Carbon Steel Small Forgings. (a)	Carbon Steel Small Forgings. (b)	Nickel-Chrome Small Forgings Heat-Treated. (a)	Nickel-Chrome Small Forgings Heat-Treated. (b)
Tensile—											
Elastic limit, tons per sq. in.	13·3	18·4	—	11·8	24·5	21·7	22·6	19·7	13·8	36·4	49·5
Yield-point, tons per sq. in.	15·6	31·8	83·2	13·7	27·0	37·4	36·5	25·0	17·5	44·7	60·5
Maximum stress, tons per sq. in.	28·2	55·0	88·2	28·4	51·9	50·1	48·5	45·1	36·2	53·7	64·3
Elongation, per cent. ..	38·5	19·0	9·5	33·5	20·0	20·0	24·5	24·0	39·0	20·5	20·0
Reduction of area, per cent.	61·5	32·3	23·7	53·4	34·9	42·0	62·0	41·9	47·1	59·2	53·0
Torsion—											
Elastic limit, tons per sq. in.	—	—	—	9·1	17·3	21·2	18·5	15·8	12·1	24·2	33·5
Apparent maximum stress, tons per sq. in. ..	—	—	—	37·7	48·0	44·6	42·0	41·9	36·5	45·8	51·8
Probable maximum stress, tons per sq. in. ..	—	—	—	23·7	36·3	33·4	31·7	31·4	27·4	34·3	39·0
Degrees of twist	—	—	—	508 deg.	249 deg.	445 deg.	480 deg.	277 deg.	362 deg.	463 deg.	383 deg.
Impact—											
Izod .. .. ft.-lb.	73·0	15·0	25·0	17·0	6·0	31·0	65·0	10·0	14·5	20·5	44·0
Charpy .. .. ft.-lb.	23·2	8·5	17·9	13·6	6·5	19·8	36·0	9·0	11·8	18·0	25·0
Charpy .. .. kgm.	—	—	—	1·88	—	—	—	—	—	—	—
Frémont .. .. ft.-lb.	119·0	14·4	57·8	50·6	7·2	57·8	74·1	18·1	25·3	32·5	116·0
Alternating and Repeated Blow—											
Arnold .. reversals	445	388	191	480	330	115	67	300	350	220	240
Stanton .. .. blows	1,110	1,713	9,212	956	977	8,150	6,500	2,021	1,213	6,962	7,100
Sankey .. .. ft.-lb.	—	—	very good	2,600	1,620?	—	240	1,730	1,060	2,870	—
Sankey .. .. bends	—	—	—	38·0	14·2	—	3·75	15·9	21·0	21·9	—
Hardness—											
Brinell hardness number ..	117	241	387	118	237	215	196	184	153	241	300
Shore hardness number ..	18	34	50	17	32/3	35	30?	25/7	18/9	34/7	43
Figure Nos.	10	11	12	13	14	15	16	17	18	19	20

For comparison, Impact Values are stated in ft.-lb Kgm. × 7·23 = ft.-lb.

The Mechanical Properties of a given Steel when in Condition of Varying Hardness.—With a view to placing on record the response given to the different types of mechanical tests by a particular steel when placed in diverse conditions as regards hardness, a steel of the following composition was selected :—

	Per Cent.
Carbon	0·34
Manganese	0·40
Silicon	0·15
Sulphur	0·03
Phosphorus	0·03
Nickel	3·4
Chromium	0·66

This analysis is typical of a well-known steel which is employed for a variety of purposes in various heat-treated conditions.

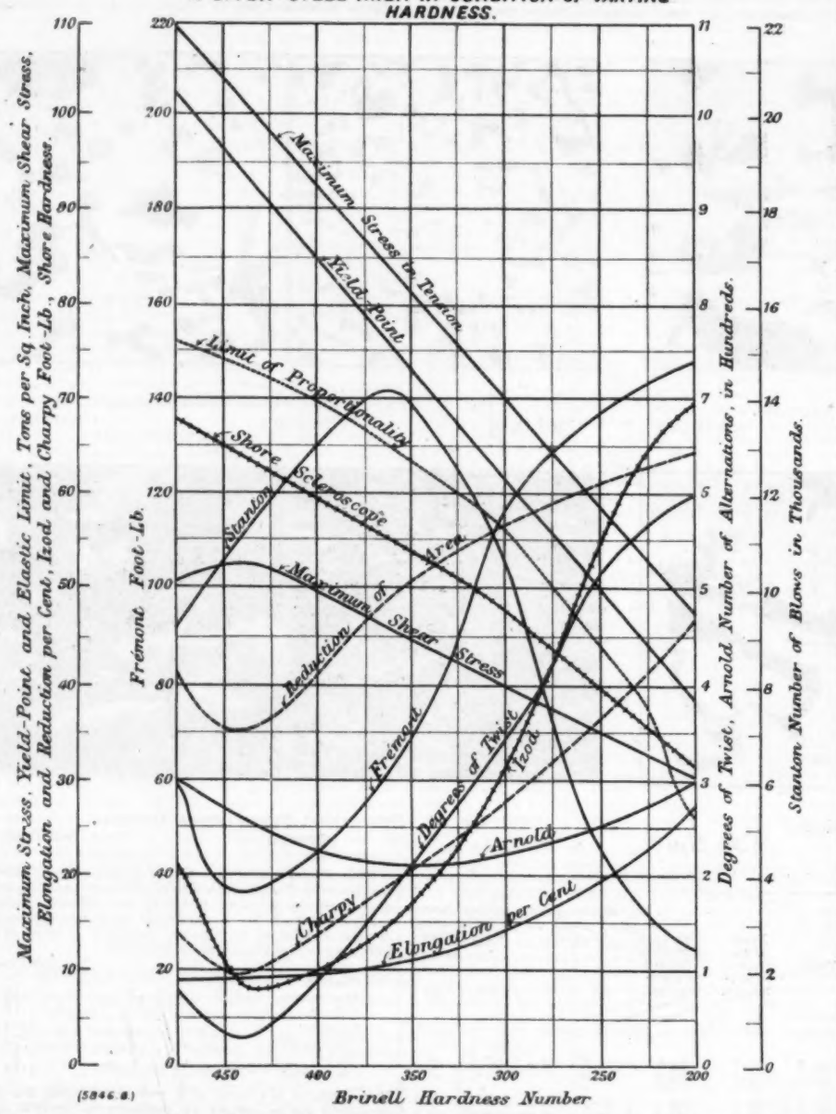
In Fig. 21, page 636, will be found a graph in which curves are drawn indicating the comparative values obtained from this steel under the tensile, torsion, hardness tests, Izod, Frémont and Charpy impact tests, Stanton, Sankey and Arnold tests. A comparison of the values is of interest.

In the first place, since mass has a considerable influence upon the results of heat-treatment, it had better be stated that the whole of these tests were performed upon the steel after heat-treatment in small section, that is, not exceeding 1½ in. diameter. The treatments were conducted under similar conditions, and in each case the tempering operation, except as regards the actual tempering temperature, was identical. Thus the results are comparable. The graph indicates the relationship of the values obtained from the different forms of tests, but only under limited conditions. This may appear to largely vitiate the value of such a graph, but it should be borne in mind that the balance of values, that is, the relationship which the values obtained from the different tests bear to one another, is distinctly variable, and to illustrate the mechanical properties of

even one steel numerous such graphs would be necessary, each indicating the response of mechanical properties to variable conditions as regards time and temperatures associated with the heat-treatment. This expression "time and temperature" naturally applies to the velocity of heating and cooling as well as to the time at a given maximum temperature.

So susceptible to modifications in these factors are steels in general that if two or three investigators were, under laboratory conditions, to endeavour to obtain a complete set of values from a particular steel, the graphs could not be placed one upon the other, the inevitable result being that a certain amplitude of variation would be evident. Advances in technique over the last few years have, however, permitted a standardisation and consistency in consecutive works operations which permit a result, once it has been attained, to be reasonably repeated.

Fig. 21. CURVES SHEWING THE MECHANICAL PROPERTIES OF A GIVEN STEEL WHEN IN CONDITION OF VARYING HARDNESS.



(5846. 8)

Speaking generally, the varying mechanical conditions of such alloy steels produced by successful hardening followed by suitable tempering, are sufficiently indicated by their hardness. Hardness is here spoken of in the sense of resistance to penetration by a steel ball under a static load. When the steel is of low hardness, say, 200 Brinell number, it may reasonably be considered to have a tensile strength of 45 tons to 50 tons, accompanied by a high ductility as measured in terms of elongation and reduction of area; a high resistance to rupture under any form of notched-bar impact test; a good value under the Arnold alternating-stress test, but an indifferent value under the standard blow of the Stanton test. Incidentally, it will have a true elastic limit in the neighbourhood of 25 tons.

With a Brinell hardness of 275, the tensile strength will be increased to 60 tons to 65 tons, with an increase in the maximum stress in torsion. The ductility will show a substantial decrease, whether judged by the elongation and reduction of area in the tensile or the degrees of twist in the torsion test. The energy absorbed by notched-impact test-pieces will be found at a lower value. Incidentally, the elastic limit in tension will be raised to about 40 tons to 50 tons, and the resistance under the Stanton test will be very considerably increased.

With still greater hardness the same general law is followed, the elastic range being steadily increased. It is not, however, necessary to discuss this graph in detail as it can be carefully analysed by anyone interested. One or two features, however, are distinctly worth noting, namely:—

(*a*) The Stanton test attains a maximum of 14,000 blows with a hardness value of about 350, afterwards decreasing.

(*b*) The Arnold test falls to a minimum at about this same value, and then rises again.

One further interesting feature is the increase in toughness of the material after passing the hardness number of 450.

It will be noted that successful hardening was stipulated. This involves heating to a suitable temperature for proper length of time, followed by efficient quenching. For instance, it is clear that with increase in dimensions of the piece, efficient quenching becomes relatively difficult, unless suitable steels are employed containing adequate proportions of nickel, chromium, or like elements to balance the effect of mass. The author has, however, dealt with this part of the subject elsewhere.* Heating at too high a temperature or quenching from too low a temperature will also influence the results of mechanical properties, and with the same hardness number the values may vary considerably. The yield, true elastic range, elongation and reduction of area may vary very much, whilst even the maximum stress may be affected to some extent. The values in the auxiliary tests are also capable of much variation under such conditions. The rate of cooling after tempering has a considerable effect in alloy steels with regard to the response they give to the notched-bar impact test.

Since in general steelworks practice, minor variations are inevitable, and since such variations do modify the relationship which the values from the different tests bear to each other, it is of interest to the engineer to form a concrete idea of the relative importance of such values in relationship to the different types of work which his different parts are expected successfully to meet. Any steel, therefore, which is employed for a particular purpose should be carefully studied, and every consideration should be given to the possible conditions of treatment which the mass of the part and particular works conditions permit. In this direction the assistance which the metallurgist may give to the engineer cannot help but be of considerable service.

Variations in the Mechanical Properties in Steels of the Same Hardness.—This matter has already been discussed, and it is proposed to give here the values obtained from a steel of the same composition as that dealt with in the foregoing section, but treated in such a way that although the tensile figures are practically the same, the notched-bar tests are very different. One possessing "brittleness" under the notched-bar tests, whilst the other is quite tough, and gives a high value for energy absorbed during breaking under that form of test. The steel employed is one forming part of the previous investigation. It was put into the 60 tons to 65 tons per square inch, maximum stress tensile condition. The notched brittle example was produced by a slow cooling from the tempering temperature, whilst the notched tough condition was obtained by water quenching from that temperature. (A) is the low-impact material, whilst (B) is the high-impact one. The figures in the following table are instructive.

——	A.	B.
Arnold test... ...	230	224
Charpy test ...	16·6 ft.-lb.	30·4 ft.-lb.
Izod test	11 ft.-lb.	63 ft.-lb.
Frémont test ...	9 kgm. 12°	20 kgm. 60°

It will be seen that the Izod impact test shows great disparity in the materials, a ratio of something like 6 to 1 existing. The Charpy and Frémont show less disparity, the ratio being 2 to 1, whilst the Arnold alternating-stress test fails to discriminate between the two materials. The latter test must, however, be admitted to successfully determine the comparative freedom or otherwise from true brittleness.

Having in mind the punishment which any steel receives in going through the Arnold alternating-stress test, it would be illogical to assume that a steel which gives a good value under such punishment is in a brittle condition.

Conclusions.—In conclusion it is considered:—

1. That all the different forms of tests which have been devised for the mechanical testing of steel bring out some information of interest. The information, however, derived from any particular test needs carefully considering by the engineer in relation to the kind of work which he is calling upon his part to do.

2. Real brittleness occurs with much less frequency than appears to be generally imagined. As a result of careful investigation, cases of "apparent" brittleness of the material can be frequently shown to be free from real brittleness.

3. Notched-bar brittleness must be dissociated from true brittleness, since whilst notched-bar brittleness is always associated with true brittleness, true brittleness does not necessarily accompany notched-bar brittleness.

4. The tensile test is fundamental, the other forms of mechanical testing being auxiliary and useful in their way for supplementing our knowledge of steels when required for specific purposes.

The author has much pleasure in thanking Dr. Arnold, F.R.S., for kindly putting through the Arnold alternating-stress tests on his original machine, installed at the Sheffield University. He is also indebted to Sir Robert Hadfield, Bart., F.R.S., Vice-President, for kindly undertaking to execute the Frémont tests on his machine, which, by the way, the author believes to be the only one in existence in this country. He would also like to thank Messrs. C. A. Parsons & Co. for kindly putting through the Sankey tests.

Before closing, the author would like to thank Messrs. Thos. Firth & Sons, Limited, and Messrs. John Brown & Co., Limited, for permission to utilise the results of investigations carried out in the Brown-Firth Research Laboratories. He would also like to record his appreciation of the interest taken in the preparation of the paper by Mr. J. Rossiter Hoyle, Vice-President, and Mr. F. C. Fairholme. He is greatly indebted to the members of the research laboratory staff, particularly Messrs. G. R. Bolsover, Assoc.Met., and G. Stanfield, M.Eng., B.Sc., for their assistance in the investigations.

The paper is illustrated by five plates and two figures in the letterpress, and is accompanied by two appendices with one figure.

(To be continued.)

* Journal of the Aeronautical Society, 1917.

"PARAGON" INTERNAL-COMBUSTION ENGINES AND ELECTRICAL POWER TRANSMISSION SYSTEM IN FRANCE.—Although the Germans left the large works at Jeumont, France, in a thoroughly smashed-up position, a large portion of the buildings have been saved, together with a number of items of the plant. A Commission has been sent to America to obtain the further machinery to enable the works to start again, and in about six months' time "Paragon" machinery will be available for France and French Colonies, for which Captain Lucien Failon, of Paris, is representative.

THE PATENT OFFICE LIBRARY.

To the Editor of Engineering.

SIR,—Although the war has been concluded for some months and the Peace Treaty is about to be signed, the Patent Office Library still closes at 5 p.m., as during the war. Yet the patent business is improving in this country, and this year is so far a record year as regards the number of applications filed. It is a matter of surprise to the public that this regulation is kept in force and the Library is not kept open till 8 o'clock, for there are many who, like the writer, would be glad to avail themselves of this extension of time to make searches and the like work, which they cannot do in the day time. The restricted and unjustifiable limitation of hours the Library was kept open during the last four and a-half years has been a great source of annoyance and irritation to the public. I must ask: Is the Library open for the benefit of the public or that of the Patent Office authorities?

Yours truly,
"MERNOK."

London, May 12.

DRAUGHTSMEN.

To the Editor of Engineering.

SIR,—The chairman of the National Executive of the A.E.S.D., in his alleged "reply" to "O.L.D." displays a considerable command of the gentle art of controversial camouflage, but in spite of this he fails to answer the point raised by "O.L.D.," which was the "advanced labour policy ideas" of Mr. Walker and his kind.

It is becoming more apparent every day that it is the object of a certain notorious clique (who have gained a measure of control grotesquely disproportionate to their numerical strength) to prostitute the energies and funds of the association to the furtherance of the interests of one particular political party, and in support of one particular school of political thought. "O.L.D." was only voicing the opinion of the average, and unfortunately inarticulate member, in objecting to these political fanatics, throwing the apple of discord into the hitherto fairly harmonious circle of draughtsmen. To judge by the "Draughtsman" the official organ of the society, one would think that the primary object of the A.E.S.D. was to help to revive the rather doubtful electoral fortunes of that party, whose banner is the red flag and whose war-cry is class hatred.

Mr. Walker pours forth a torrent of abuse which I will leave "O.L.D." to reply to, and waxes eloquent over the "democratic" methods by which the A.E.S.D. is controlled. He informs us that "on vital matters a referendum is taken." Perhaps Mr. Walker will be good enough to inform us: Was a referendum taken on the proposal to affiliate with the Trades Union Congress? Or on the proposal to affiliate with the Labour Party? Or on the proposal to increase the subscription by 233 per cent.? Are not these vital matters?

When we have his answers, draughtsmen will be able to appreciate his "democratic" protestations at their proper value. He assures us that the executive is merely an administrative body. Does it merely administer the funds of the society? If so, who authorised a payment from the funds of the association to the Labour Research Department, which I believe is a purely party organisation?

Although I am one of the older members of the A.E.S.D. I have no recollection of being consulted by referendum or otherwise on this "vital" matter.

Yours faithfully,
"SCRUTATOR."

"THE METALLURGICAL INFORMATION REQUIRED BY ENGINEERS."

To the Editor of Engineering.

SIR,—As one who, during the past few years has been responsible for the acceptance and rejection of engineers' supplies, I cannot agree with their suggested lack of "interest" in the criteria of materials for the setting-up of which Colonel Jenkins makes metallurgists responsible.

Aeroplane engine crankshafts are somewhat specialised products, and it is scarcely logical to argue from a particular case such as this, that, generally engineers have "no interest" in the elongation and reduction of area of a material and "little interest" in the ultimate strength, to take a few of the author's strictures.

In modern high-speed machinery the construction of the revolving parts is frequently such that the whole is made up of intricate shapes either forged, machined or built up of distinct parts, for which the stresses may not be wholly determinable. Errors in machining, assembly, or the impossibility of calculating the exact stress distribution make it essential that there shall be some quality of the materials used which will permit of the stresses being made or less equalised. Elongation provides the necessary safety-valve at points where without it the stresses may become dangerously high, leading to the formation of incipient cracks. High-grade cast-iron, if it possessed this quality of elongating to any degree, would in many cases be a more suitable and a cheaper material where now steel is used.

To state that the value of the ultimate strength is of "little interest" except as giving a margin of strength is surely belittling the importance of the mechanical test. Its relation to the elastic limit is one of the guides in arriving at factors of safety. The continued omission of ultimate strength in specifications would inevitably lead to the undue raising of the elastic limit relatively to it. As is well known, such a condition is easily obtained particularly in ferrous metals, but I question if many engineers will care to use materials having a relatively high *artificial* elastic limit with reference to the ultimate strength.

An intelligent understanding of the relation of the ductile to the plastic elongation in conjunction with the reduction of area ensures, speaking generally, proper treatment in manufacture, and a correspondingly reduced liability to failure of the material in use. The specifying of certain standards of physical quality, it is well known and appreciated, has the double effect of securing uniformity in supplies as well as the gradual improvement in their suitability for particular work.

The author of the paper has used the word "interest" in a particular sense which has no relation to that interest which all engineers have in anything appertaining to their materials. This other interest is that which makes the engineer, that thirst for knowledge which is the incentive he, in company with the metallurgist, has in investigating the real meaning of all such tests as the Brinell, Izod, &c., mentioned in the paper referred to.

Yours faithfully,
D. A. HACKETT.

CRITICAL SPEED OF SHAFTS.

To the Editor of Engineering.

SIR,—Kindly correct a slip in the present writer's letter of May 7, and in the last sentence read "reduction of critical period" for "reduction of critical speed."

Professor Hahn is the translator of Stodola's "Text-Book on Steam Turbines" into French, and his paper under notice is an analytical generalisation of the problems in Chapter IV.

My note was intended to give his paper its place in the bibliography of the subject, and the digression on aeronautical application was somewhat irrelevant and unnecessary.

The manifesto on comparative British progress, signed by Mr. Cowley and countersigned by Mr. Levy, seems heavy metal in reply, and raises a much wider question.

No one is more keenly aware than the writer how much British progress during the war is due to the unselfish way in which professional mathematicians have placed themselves at the disposal of technical engineers.

The latter have exploited them thoroughly, and one of the results is a crop of analytical generalisations sufficient to support many reputations for years.

What might not be achieved if men of this calibre were attracted to the permanent study, at first hand, of such engineering problems as can only be handled with ease and confidence by professional mathematicians!

I am, &c.,
A. R. LOW.

London, May 10.

THE INDUSTRIAL RECONSTRUCTION COUNCIL.—Following upon the statements made in a number of our past issues we are now informed that the Industrial Reconstruction Council is continuing a further series of conferences on questions of moment, full particulars concerning which can be obtained from the offices of the Council, 2 and 4, Tudor-street, E.C. 4.

NON-FERROUS METALS.—The following are the particulars of the stocks (exclusive of old metal and scrap) in this country in possession of the Minister of Munitions on the 1st inst: Copper, 51,130 tons; spelter, G.O.B., 26,912 tons; spelter, refined, 7,057 tons; aluminium, 11,542 tons; soft pig-lead, 109,012 tons; nickel, 2,567 tons; antimony regulus, 4,461 tons.

THE PORT OF HULL ANNUAL.—The Port of Hull Annual for 1919 is edited by Mr. H. E. Cooper Newham, and is published at the office of *The Hull Trade and Transit*, at the price of 2*s.* 6*d.* It gives a large amount of interesting information on the town and port, the shipping and trade of Hull, the dock facilities, the shipbuilding and engineering industries, the railway and canal connections, &c. It contains a chapter descriptive of the port and its trade in French and in Spanish, and will be found useful for reference purposes by a wide commercial and industrial circle.

DESTROYER TRUSTY.—Messrs. J. Samuel White and Co., Limited, East Cowes, Isle of Wight, delivered the ocean-going torpedo-boat destroyer Trusty to the Admiralty on Friday, the 9th inst. This war vessel, which is of 1,000 tons displacement and 28,000 shaft horse-power, was launched on November 6 last. She has been constructed, engined and fully equipped by the firm, her propelling machinery consisting of Brown-Curtis geared turbines, supplied with steam by White-Forster water-tube oil-fired boilers. The Trusty, which is the seventieth torpedo vessel completed at the East Cowes shipyard, attained a speed of 35¼ knots on the measured mile during her acceptance trials.

SPITSBERGEN.—The Northern Exploration Company have received cable advice that the first steamer this season, arrived at Lowe Sound, Spitsbergen, last Saturday. A second boat is leaving Tromso this week, and a third steamer is leaving Aberdeen carrying engineers, scientists, geologists, prospectors and a large number of miners, with machinery, mining equipment, provisions and stores, for the purpose of working and developing the Northern Exploration Company's extensive properties on the Western Coast of Spitsbergen. Wireless stations are being erected, and should soon be in operation at Recherché Bay, Lowe Sound, and King's Bay, each of which will be in communication with the central wireless station at Green Harbour.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 16, at 7.30 p.m., at 39, Victoria-street, Westminster, S.W., Lecturette, "Notched-Bar Tests," by Major H. P. Philpot, R.A.F. (Member). Friday, May 23, at 7.30 p.m., Lecturette "Reinforced Concrete Construction," by Mr. George Allen (Member).

THE INSTITUTE OF METALS.—Monday, May 19, at 8 p.m., at Caxton Hall, Caxton-street, Westminster, when the ninth annual May Lecture will be delivered by Professor F. Soddy, F.R.S., on "Radio Activity."

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, May 20, 1919, at 5.30 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, W.C. 2. The following paper will be read: "The Chemist and Engineer in Relation to the Petroleum Industry," by Mr. F. Mollwo Perkin, Ph.D., F.I.C., F.C.S., and Mr. T. C. Palmer, Assoc.M.Inst.C.E. The chair will be taken by the president, Sir Frederick W. Black, K.C.B.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, May 21, at 5 p.m., at 70, Victoria-street, Westminster. Papers to be read: (1) "Further Measurements on the Rate of Ascent of Pilot Balloons," by Captain C. J. P. Cave, R.E., and Mr. J. S. Dines, M.A.; (2) "Report on the Phenological Observations for 1918," by Mr. J. E. Clark, B.Sc., and Mr. H. B. Adames.

THE ROYAL SOCIETY OF ARTS.—Wednesday afternoon, May 21, a paper on "The principles of Japanese Design," will be read by Sir Francis Taylor Piggott, M.A., LL.M., Chief Justice of Hong Kong, 1905–12. The chair will be taken at 4.30 p.m. by Mr. John Slater, F.R.I.B.A., Member of the Council of the Society.

THE CONCRETE INSTITUTE.—Thursday, May 22, in the Lecture Hall at Denison House, 296, Vauxhall Bridge Road, Tenth annual general meeting. Paper by Professor P. G. H. Boswell, D.Sc., on "The Geology of Aggregates and Sands" (lantern).

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, May 22, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. "Electrical Phenomena Occurring in High Atmospheric Levels," by Dr. S. Chapman.

THE SURVEYORS' INSTITUTION.—Monday, May 26, 1919, at 5 o'clock. The annual general meeting of the Institution, to receive the report of the Council and the announcement of the result of the election of officers for the ensuing year. The prizes awarded to successful candidates in connection with the recent Preliminary and Professional Examinations will be presented by the President at the annual general meeting.

THE LATE MR. JAMES REID.—We regret to have to announce the death on Saturday, the 10th inst., of Mr. James Reid, who for many years held high positions at the Queen's Engineering Works, Bedford. Mr. Reid was 73 years of age. He first became acquainted with Mr. W. H. Allen forty-seven years ago, and was appointed foreman in the year 1880. A few years after he took the position of works manager, and served in that capacity until June, 1915, when, owing to his advancing years, he retired from active service at the Queen's Engineering Works. On the outbreak of war he came and offered his services again to the firm in connection with the Government work which they were doing, and continued as an inspector of aeroplane engines until March of the present year.

THE DYE INDUSTRY.—The Board of Trade desire to give notice that, in accordance with the procedure laid down in the White Paper (No. Cd. 9194) setting out the scheme for affording State assistance to the dye industry, the Trade and Licensing Committee have appointed a Licensing Sub-Committee to deal with all questions relating to the administration of the Prohibition of Import (No. 29) Proclamation, 1919, prohibiting the import of dyestuffs, &c., into the United Kingdom. The chairman of the Trade and Licensing Committee (Lord Colwyn) is also the chairman of the Licensing Sub-Committee. The offices of the Licensing Sub-Committee are at Danlee Buildings, 53, Spring Gardens, Manchester, and any communications should be addressed to the Secretary (Mr. W. Graham) at that address.

MEASURING SMALL QUANTITIES OF MOISTURE IN GASES.—The device for the rapid determination of small amounts of moisture in technical gases, proposed by A. J. Crockatt, M.Sc., and R. B. Forster, D.Sc., in the journal of the Society of Chemistry Industry, April 30, 1919, is a hygrometer. Ordinary spun fibres they found unsuitable for the purpose when highly-spun, because those fibres contract in moist atmospheres; of the suitable, expanding closely spun fibres they consider artificial Chardonnet silk preferable to natural silk, and also to hair. The Chardonnet silk responds rapidly to changes in the humidity and can easily be obtained in long fibres of uniform diameter and sufficient mechanical strength. In the instrument described a thread of 20-in. length is attached at its upper end to a hook and at its lower end to the short arm of a magnifying lever, the case being metallic; the lever mentioned actuates the pointer through the intermediation of a second lever. Air is continuously drawn through the instrument; one scale division corresponds to 0·05 per cent. of moisture. The hygrometer, which was worked out in the laboratories of the dye works of Messrs. Levinstein, is recommended for textile works, sulphuric acid works, producer gas manufacture and blast furnace practice (air supply). From the discussion it would appear, however, that the instrument had only been tried on one gas, ethylene; the moisture of the gas might make a difference in the long run.

THE MECHANICAL PROPERTIES OF STEEL.

(*For Description, see Page* 634.)

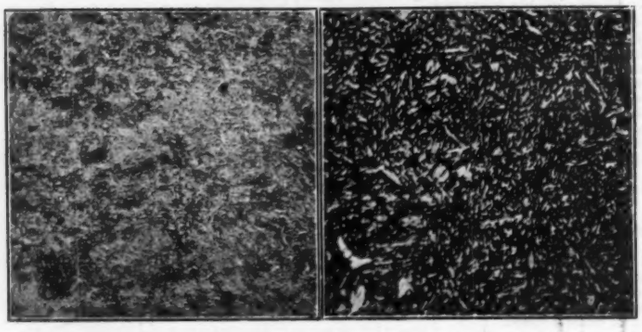


Fig. 12. Spring Steel.
× 100 Diam. (Etched.) × 500 Diam.

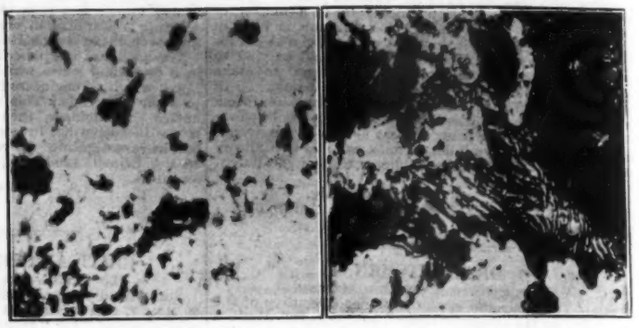


Fig. 13. Propeller Shaft.
× 100 Diam. (Etched.) × 500 Diam.

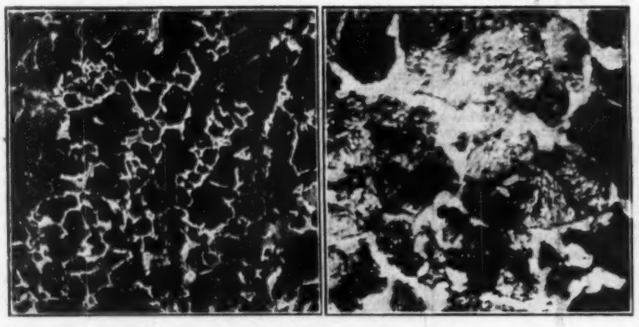


Fig. 14. Tyre.
× 100 Diam. (Etched.) × 500 Diam.

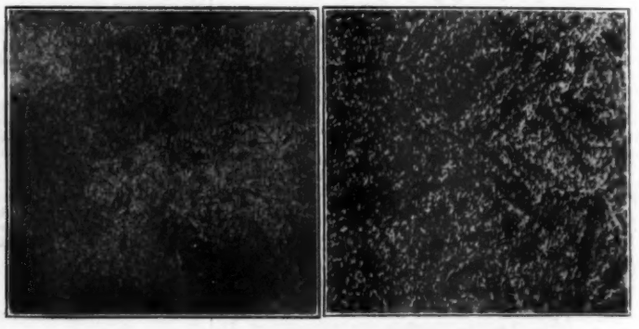


Fig. 15. Large Mass Heat-Treated Nickel-Chrome.
× 100 Diam. (Etched.) × 500 Diam.

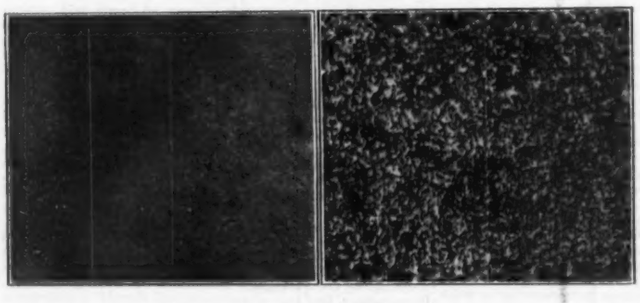


Fig. 16. Very Large Mass Heat-Treated Nickel-Chrome.
× 100 Diam. (Etched.) × 500 Diam.

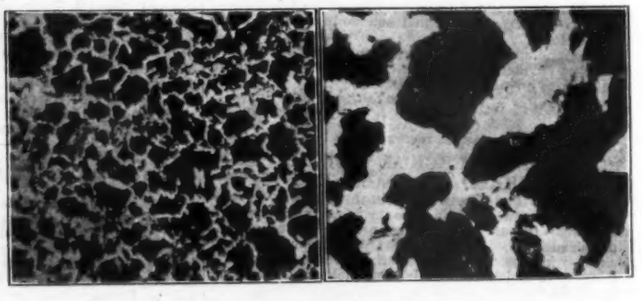


Fig. 17. 0·50 per Cent. Carbon Steel Forging.
× 100 Diam. (Etched.) × 500 Diam.

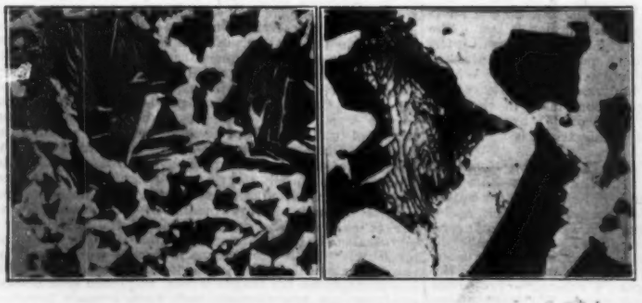


Fig. 18. 0·40 per Cent. Carbon Steel Forging.
× 100 Diam. (Etched.) × 500 Diam.

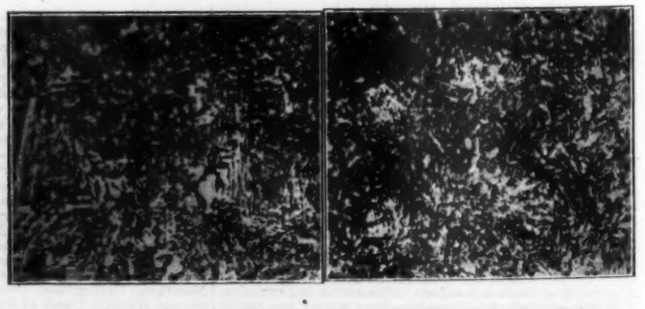


Fig. 19. Heat-Treated Nickel-Chrome Small Forging.
× 500 Diam. (Etched.)

Fig. 20. Heat-Treated Forging 60 to 65 Tons.
× 500 Diam.

CONCRETE SHIPBUILDING AT BARROW-IN-FURNESS.

(*For Description, see Page 624.*)

FIG. 15.

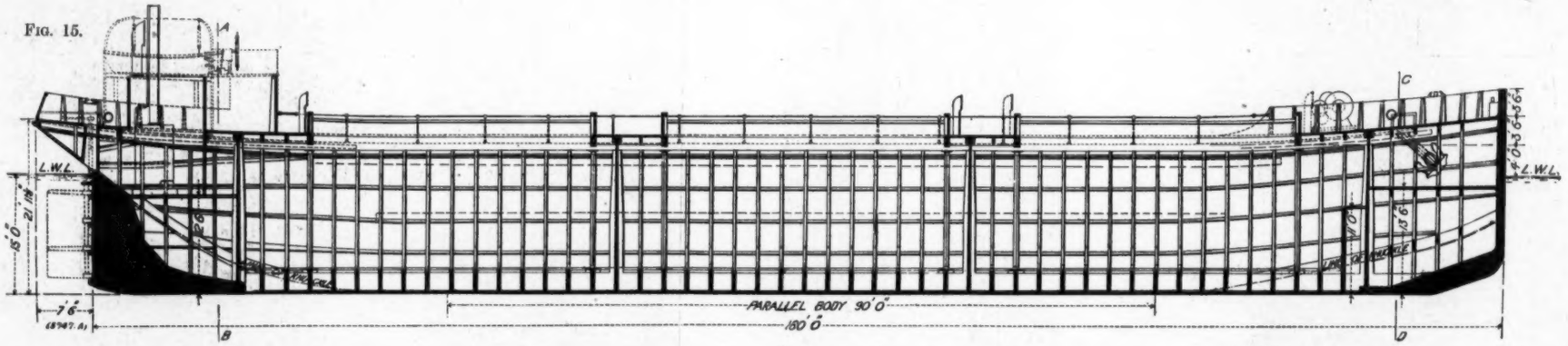


FIG. 16.

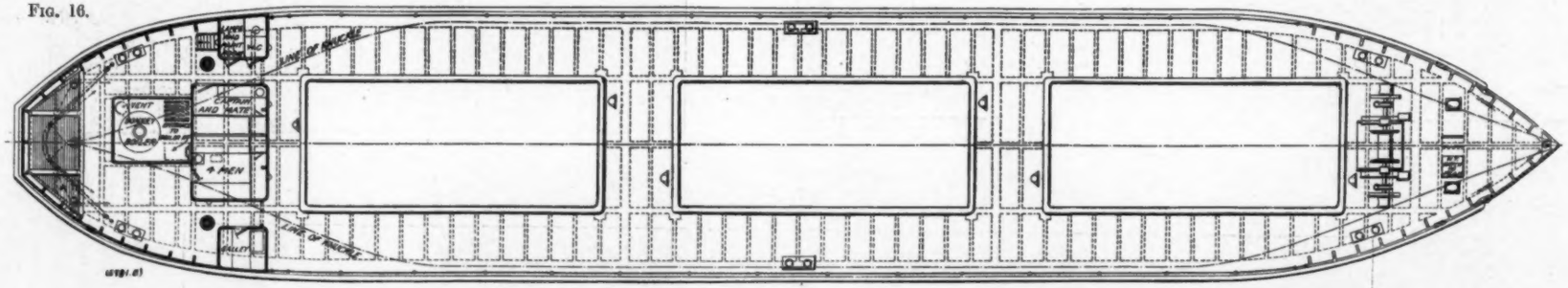


FIG. 17.

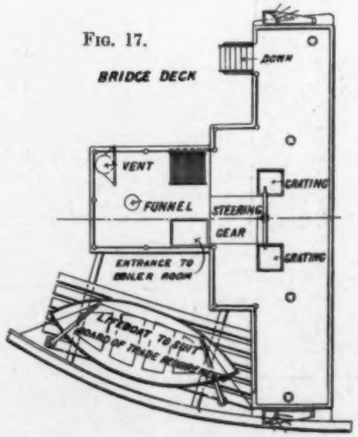


Fig. 18. CROSS SECTION A-B

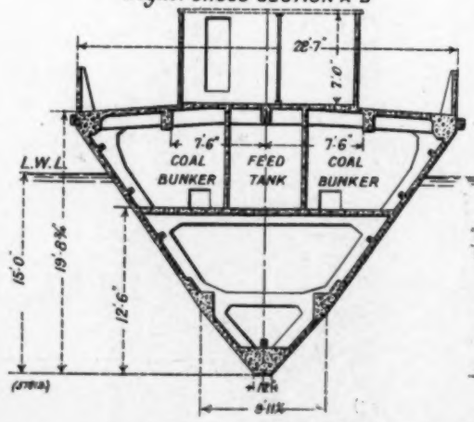


Fig. 19. MIDSHIP SECTION.

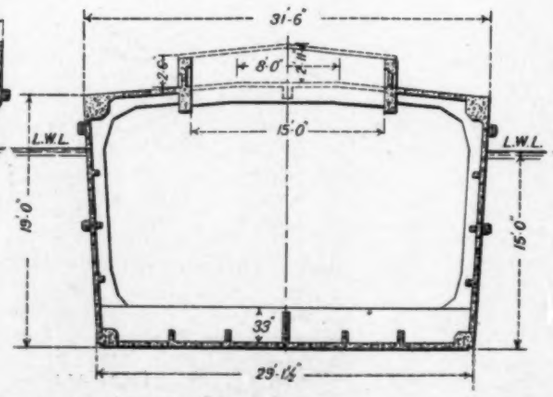
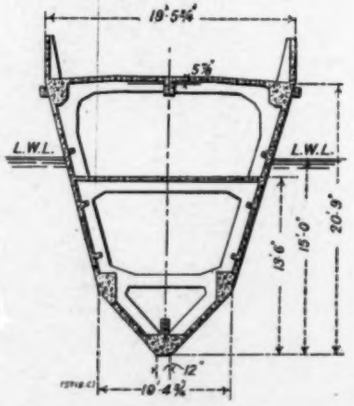


Fig. 20. CROSS SECTION C-D



FIGS. 15 TO 20. 1000-TON SEA-GOING DUMB BARGE.

(*To face page 626.*)

CONCRETE SHIPBUILDING AT BARROW-IN-FURNESS.

(*For Description, see Page* 624.)

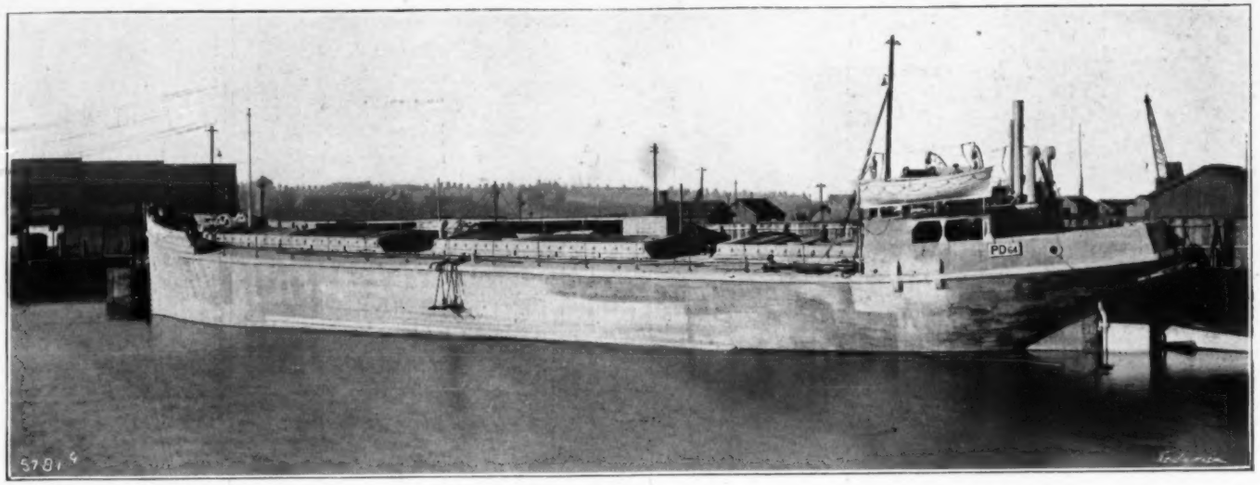


FIG. 21.

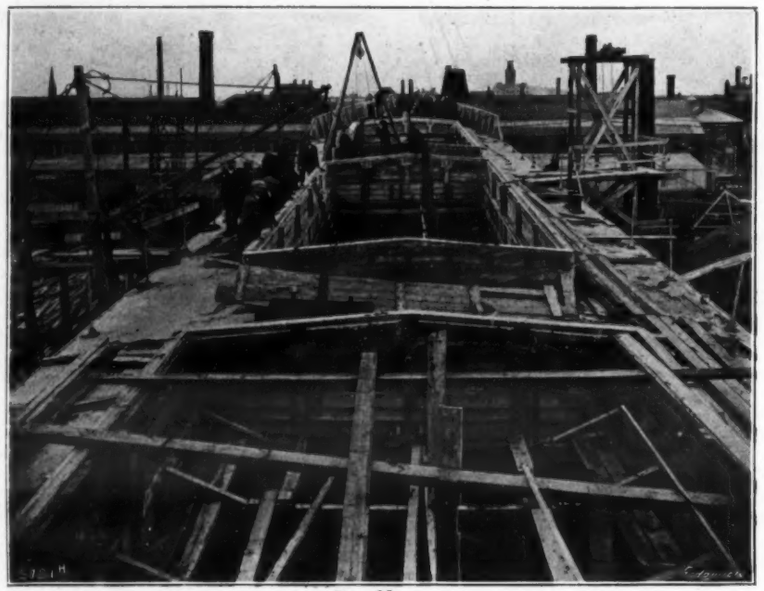
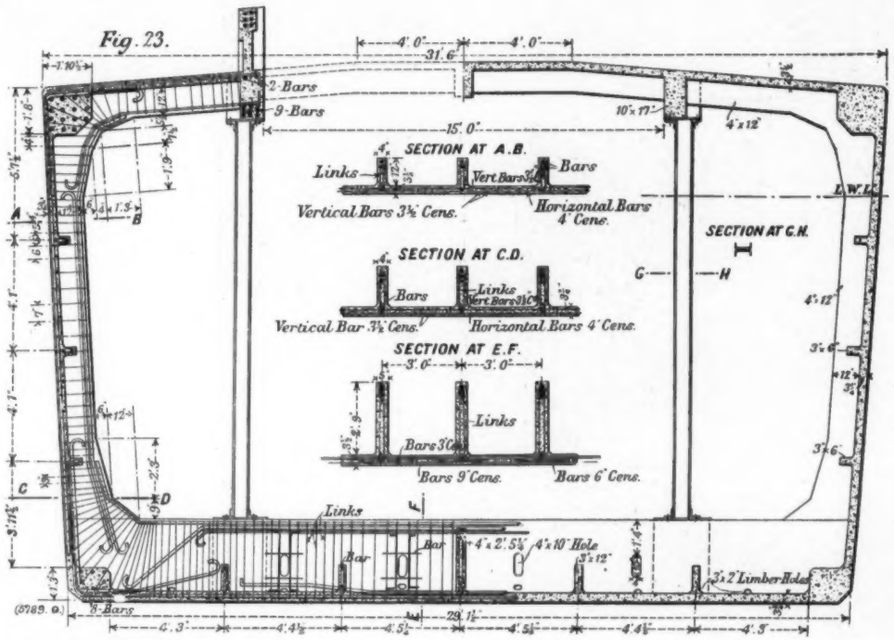


FIG. 22.



FIGS. 21 TO 23. 1000-TON SEA-GOING DUMB BARGE.

CONCRETE SHIPBUILDING AT BARROW-IN-FURNESS.

(*For Description, see Page* 624.)

FIG. 25.

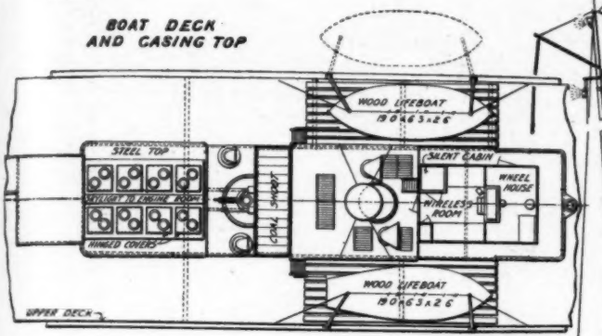


FIG. 24.

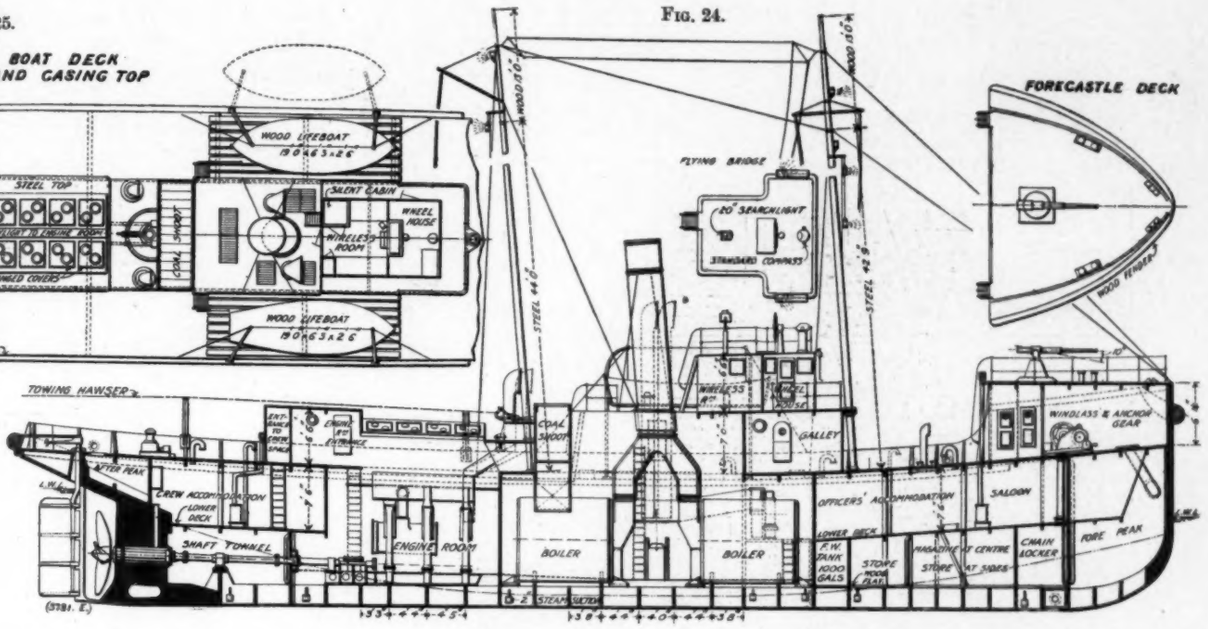


FIG. 26.

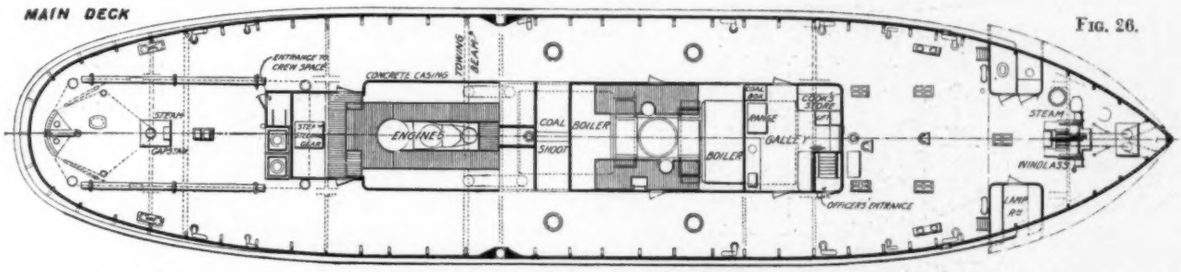


FIG. 27.

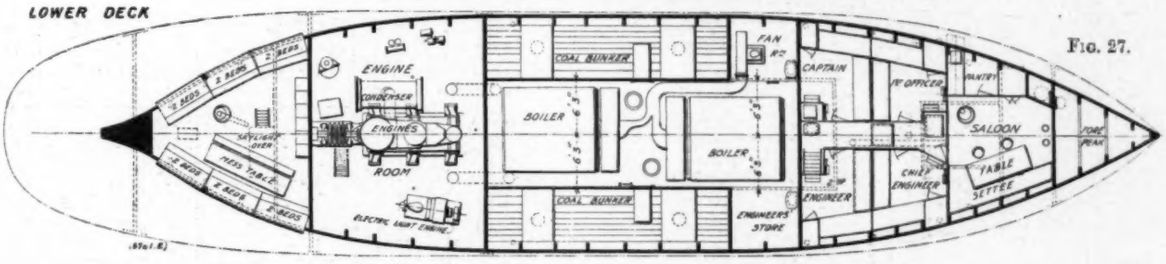
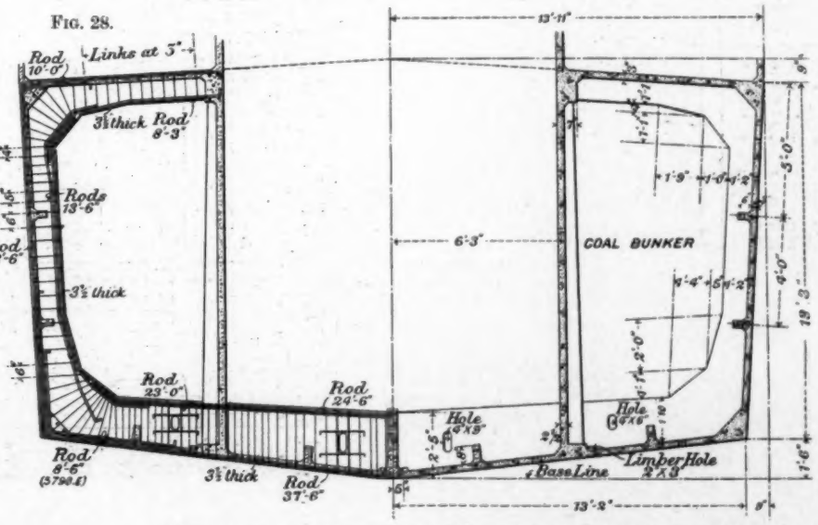


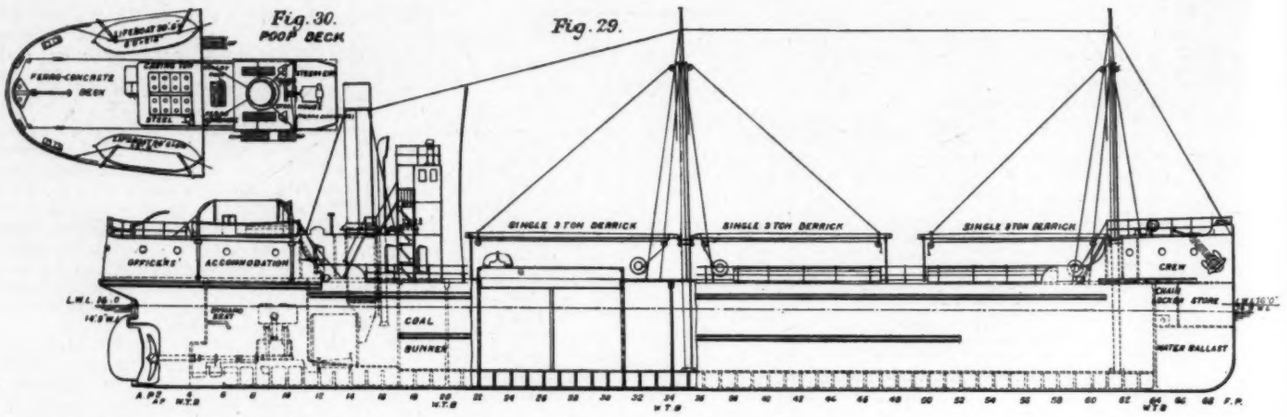
FIG. 28.

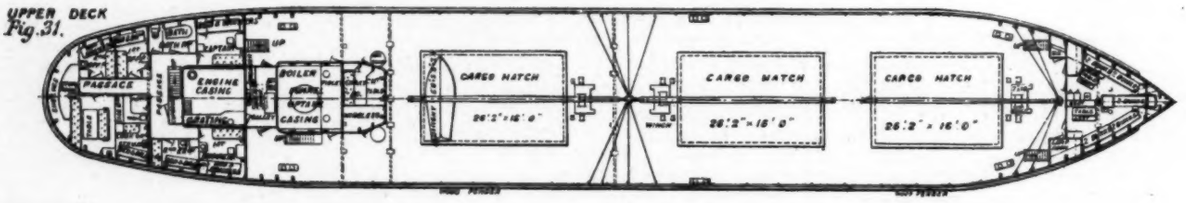


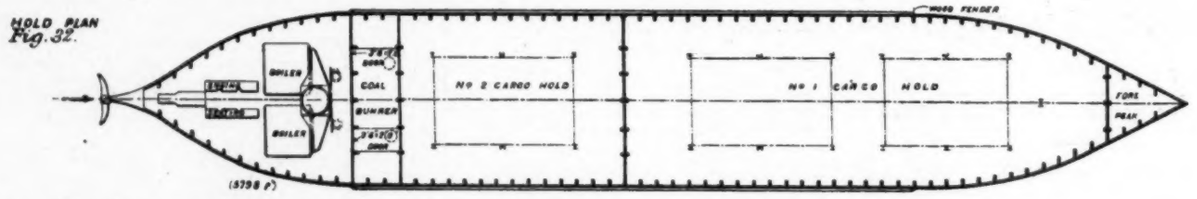
FIGS. 24 TO 28. STEAM TUG 125 FT. BETWEEN PERPENDICULARS.

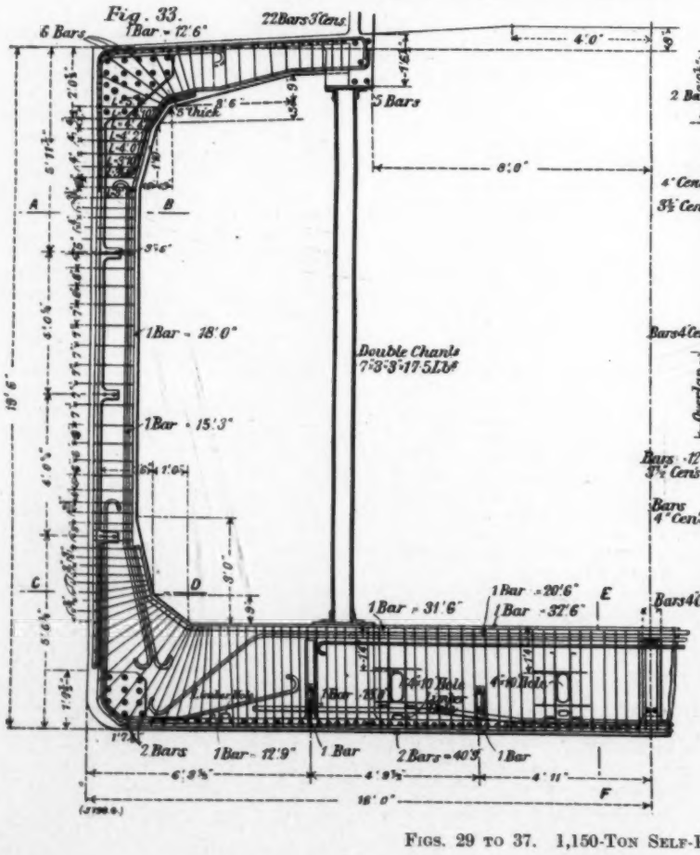
CONCRETE SHIPBUILDING AT BARROW-IN-FURNESS.

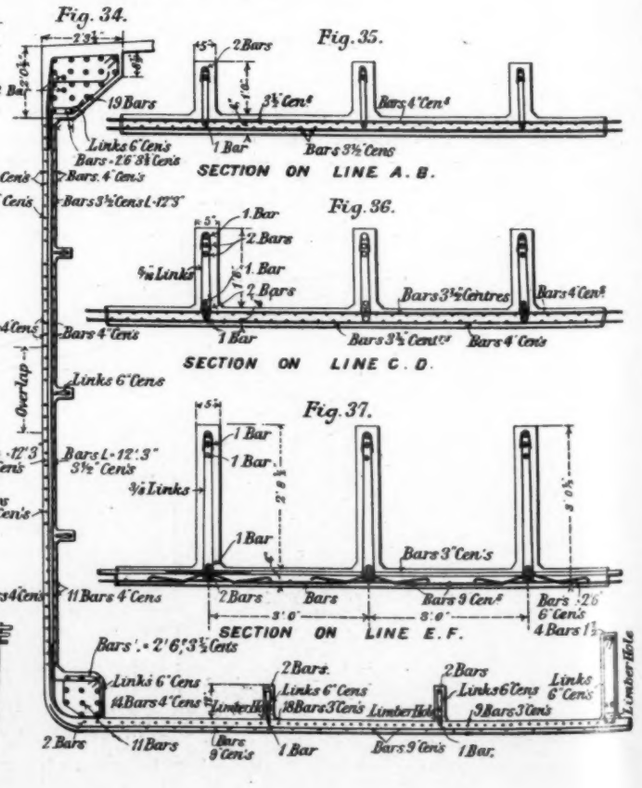
(*For Description, see Page 624.*)











FIGS. 29 TO 37. 1,150-TON SELF-PROPELLED CARGO VESSEL.

(*To face page 627.*)

AGENTS FOR "ENGINEERING."

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NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 637.

ENGINEERING.

FRIDAY, MAY 16, 1919.

DIRECTIVE AND ADMINISTRATIVE WORKS MANAGEMENT.

ON the general question of works efficiency, a great deal has been said and written within recent times, but it is worthy of note that while the relations between capital and labour and the questions of increased output per worker have been singled out for full and free discussion, the question of the efficiency of the management of works has been largely ignored. This is unfortunate, for it can be stated with certainty that inefficient management can be a much more potent factor in retarding production and lowering the over-all efficiency of the works than many of those more widely discussed. In most of the large works of the present time the managerial function may be conveniently divided into two main branches: Directive and Administrative. Of these the directive is charged with the making of decisions as to the general policy of the works, nature and extent of work to be undertaken, delivery sequence of jobs, &c., such decisions representing the considered judgment of the board of directors, and being communicated by the managing director to the administrative branch, on which latter falls the responsibility of giving practical effect to the decisions of the directive branch. At the head of the administrative staff is the works manager, responsible for the organisation of an executive staff, co-ordination of departments, continuous employment of machinery and workers on suitable work, co-ordination of drawing office and outside work, preservation of industrial peace within the works, increase of output, and reduction of costs, &c., and it is with some of the problems of his onerous position that we propose to deal.

With the increase in the size of works and factories, which has been a characteristic of modern industrial development, the problem of management has become of ever-increasing importance and complexity, and it is certain that the problems to be faced in the near future in dealing with organised labour and the other factors bearing upon economic production will call for the exercise of qualities of a higher order than have sufficed in the past. Where a business has been built up by a craftsman step by step, and where the effort is directed solely to the production of an article of which every phase of manufacture is known to, and controlled by, the principal, the conditions under which the maximum efficiency of management may be expected are fulfilled. These conditions are, however, only possible in a comparatively small works and are not met with in any of the large modern engineering or shipbuilding works where the size of the works and the variety of production make it a physical impossibility for one man to attend to all the administrative and executive duties of management. Successive stages of works development necessarily involved the delegation of certain duties of supervision to subordinates selected for their special knowledge of the work or process involved, the appointment of foremen of departments, head foremen, and assistant or departmental managers, all leading to the works executive staff as it is commonly met with to-day.

Of the duties of the works manager by far the most important, and by no means the least difficult, is the co-ordination and direction of the efforts of his staff in the efficient and harmonious discharge of their duties in order to ensure the maximum output and efficiency of workers and machinery. Success in this essential duty is by no means easy of attainment, but once attained it forms a very substantial base upon which complete success may be built, indeed, it is hardly overstating the case to say that the success or failure of any large industrial concern depends in a very large measure upon the degree of confidence and enthusiasm which the works manager can inspire in his staff, and consequently in the efficiency of departments and in the degree of co-operation which exists between departments. The natural ability to inspire this confidence is, unfortunately, rare, even in those whose technical qualifications are of the highest, but the breadth of outlook engendered by a liberal education, wide reading, and an intelligent study of human nature, is a substitute which may be acquired with advanatge by all who aspire to control and direct others, whether in the capacity of directors, managers or foremen. Failure to recognise the necessity of inspiring confidence in subordinates is one of the most common errors of those holding high positions in industrial concerns, and probably conduces more directly to inefficiency in the works than does the indifference or veiled hostility of the worker. The peculiarly British practice of selecting a "practical" man as works manager may have much to commend it where the works manager is required to supply a deficiency of practical knowledge on the part of the board of directors, or managing director, but it is to be feared that the results are not always of the happiest. Too often it is the case that such a chief makes no effort to secure the interest and co-operation of his subordinates, and looks with contempt upon suggested departures from recognised methods or innovations based upon theoretical considerations.

One of the most striking features of American factory organisation is the definiteness of the position and duties of each member of the executive staff—an arrangement of which the advantages from the point of view of efficiency are perfectly obvious. Curiously enough, the tendency in this country has recently been in the direction of making a number of appointments to the executive staff, and in each case carefully avoiding any clear definition as to position and duties. Both on the score of inefficiency and of unfairness to the individuals concerned, this development is to be condemned, for a more prolific source of friction could hardly be conceived. It is quite certain that in many of our largest manufacturing concerns there exists a state of indefiniteness as to the position and responsibilities of assistant and departmental managers which is as hurtful to efficiency as it appears to be unnecessary, and no system of multiple or indefinite control for any one department can possibly yield the best results where instructions have to be issued to subordinates.

Failure to recognise and uphold the position of immediate subordinates is one of the most common causes of dissatisfaction, and, therefore, of inefficiency in dealing with a works staff. It frequently happens that a works manager in the course of a hurried run through the works notices various items not being pushed as fast as he desires. He sends direct for the foremen concerned and instructs them to put men on the job at once while the departmental manager has already given instructions, for good and sufficient reasons, to concentrate on another job. Similarly departmental managers too frequently instruct under-foremen to move men from one job to another without acquainting the head foremen with the fact. Actions such as the above create a vast amount of needless irritation and could and should easily be avoided.

The absence of co-operation between the drawing-office and the executive staff has been frequently commented upon, but it certainly is a deplorable fact that where the drawing-office does not come under the direct control of the works manager, any suggestions made by the executive staff are too often ignored, with the result that machines and men are rendered needlessly idle. In the cases of shipyards and engineering shops turning out a large variety of vessels and engines, it frequently

happens that a slight modification in the rotation of delivery of material would be of very great benefit to the works executive staff in providing work for machines or groups of workers temporarily slack or idle. As a rule the modified sequence of ordering and, therefore, of delivery of material could easily be arranged for by conference between the works staff and the drawing office staff.

In the general re-organisation of industry which is at present taking place, it is of importance to remember that expensive machinery and highly-paid labour can only be economically productive when they are utilised at their maximum capacity, and fulfilment of this condition may demand a higher degree of efficiency on the part of the works executive staff than has sufficed in the past. As a step toward this increase in efficiency, a much more general adoption of the system of conferences between the heads of all departments seems to offer hope of considerable success. A conference between the managing director, works manager, assistant managers and chief draughtsman would form a convenient occasion for the discussion of works problems of all kinds, would keep the managing director in direct touch with each department of the works, and would, incidentally, afford him an excellent opportunity of forming an accurate estimate of the capabilities of each member of the works executive staff. Meetings such as these would undoubtedly be of value to all concerned, and should provide the means for co-ordinating the work of departments and promoting increased departmental and, therefore, over-all efficiency.

Similar conferences between the works manager, assistant managers and foremen for the discussion of work coming forward, progress of work in hand, and suggested improvements in methods or plant would be equally productive of good. The fact that each responsible official was given an opportunity to express his views on matters which directly affect him and his department, would be of benefit to all ranks of the staff, while the expression of the opinions incidental to differing points of view, if capably analysed, could not fail to be helpful to the higher officials. In these days of industrial uncertainty and change, the importance of the positions occupied by the responsible officials of the executive staffs of all large industrial concerns is apt to be lost sight of in the stress of dealing with organised labour, but surely these present difficulties suggest in themselves the vital necessity for the highest efficiency in all ranks of the works executive staff.

CLUTCHES.

ALTHOUGH all engineers and most other people know what a clutch is, it is probable that few have ever troubled to define it. There is, we think, no scientific definition in general use, and it is likely that many of the definitions to be found in text-books and dictionaries will, on examination, be found to cover appliances that are certainly not clutches. An examination of the essentials of a clutch and a demonstration that these essentials will be found in all actual true clutches was made by Dr. H. S. Hele-Shaw in a lecture delivered before the Royal Institution on the 1st inst. The lecture was the first of a series of two dealing with this subject. Dr. Hele-Shaw began by stating that he had been unable to find a satisfactory definition of a clutch anywhere. Most existing definitions would be found to include the claw clutch, which, in his opinion, was not a clutch at all, but a disconnecting coupling. Webster, for instance, divided clutches into two main types—friction and claw; and the definitions of most other authors—technical or other included the claw clutches as a true clutch. The definitions in Knight's technical dictionary, in Reuleaux and the Montagu Motor Book, all failed to differentiate the claw clutch from the friction clutch.

To fix ideas, Dr. Hele-Shaw considered the case of a simple friction cone clutch, and laid it down that a clutch was a device with two parts rotating or rotatable about a common axis; which, by engagement, could transmit force; which could be connected and disconnected as gradually as desired, whatever their relative velocity; and which in the operation would not suffer injury, whatever the amount of slipping. To illustrate his point, Dr. Hele-Shaw showed a simple model consisting of a wooden slide working between vertical guides. At either side there were further wooden slides working in horizontal guides, and arranged so that when pushed inwards they pressed against the edges of the vertical slide. The whole thing was arranged in one plane. A notch was cut in the left-hand edge of the vertical slide which could engage the end of the left-hand horizontal slide. This arrangement represented the claw clutch, which the Doctor contended was not a true clutch. When it was engaged it could not be released by pulling or pushing the vertical slide, and it could not be engaged under load, since if the horizontal slide was pressed inwards against the edge of the vertical slide and the vertical slide was at the same time moved downwards, the notch slipped past the end of the horizontal slide before engagement could take place, unless the speed was very slow, and if the horizontal slide *did* by chance slip in there was a detrimental shock. This, Dr. Hele-Shaw contended, was sufficient in itself to rule out the arrangement as a true clutch. Incidentally we may say we have often enough seen a claw clutch thrown into action with the parts in motion, but confess the procedure is somewhat brutal.

The right-hand side horizontal slide on the model was arranged so that it could be pressed inwards towards the vertical slide by means of a bell-crank lever, the horizontal arm of which was arranged to carry a weight. By loading this lever the vertical slide could be held in position even with a weight placed on top of it, tending to move it downwards. The weight that the slide would carry without moving was, of course, a function of the load hung on to the bell-crank. Further, if the slide was moving downwards owing to a weight having been placed on it, it could be stopped at any point by the friction of the end of the horizontal slide applied by loading the bell-crank lever. This simple model Dr. Hele-Shaw held illustrated all the essentials and all the parts of a clutch, and all actual examples of mechanical clutches would, on examination, be found to reduce themselves to it. Before proceeding to illustrate this from examples of actual clutches, he laid down five conditions with which a good clutch should comply. He held it should be controlled, powerful, durable, self-contained and balanced. Most of these terms carry their own explanation, but it may be said that by self-contained is meant that when engaged, or disengaged, it will remain in that condition without the application of continuous external force, and by balanced that whether engaged or disengaged the centrifugal forces at any speed produce no vibration.

The remainder of the first lecture consisted of the illustration of actual clutches of various types such as those of Broadbent, Crofts, Entwhistle, Reddaway, Wiggleworth, and the Unbreakable Pulley Co., &c., by means of lantern slides. Several examples which were not clutches according to the definition adopted were first exhibited, such as the ratchet and pawl, the so-called silent ratchet and the free-wheel. If these devices had to attempt to transmit power beyond their capacity, they did not slip as a clutch should; they broke. In connection with the true friction clutches of the cone expanding-band or other types, it was shown that the greater part of the ingenuity which had gone to their design had been spent in finding some method which, in effect, was equivalent to increasing the length of the horizontal arm of the bell-crank lever of the wooden model already described. The effect of this was, of course, to enable the vertical slide to hold a greater weight with the same load. Similarly the effect of the toggles, screws and other arrangements adopted in actual clutches, was to enable greater pressure to be obtained between the two friction surfaces.

The multiple disc clutch tackled the problem of obtaining greater driving power, with the same externally applied force, in a somewhat different way. By superposing a number of plates and applying a load to the outside ones, a greater frictional effect was obtained than if the same load was applied to two plates only. The clutch was a good illustration of the falsity of the so-called law that friction was independent of surface. What was really intended to be conveyed by this law was that friction varies directly as the pressure per unit area of surface. The multiple disc clutch was invented by Thomas Aldridge Weston, of Birmingham, whose specification was dated January, 1863. The clutch was usually spoken of as of American origin, but that was incorrect. What was true was that the clutch had first been developed commercially in America. There was a very pretty device detailed in Weston's specification to enable the clutch to be screw-operated and to be freed when rotating. In an ordinary way this could not be done; the plates were screwed up together and the clutch could then transmit force; but to release it the clutch had to be stopped before one could release the screw and free the plates. In the device referred to the arbor carrying the plates was screwed at one end and carried a nut in the form of a handwheel. This nut on the outside of its boss had a second thread of opposite hand, on which a second handwheel nut was carried. By applying friction to the rim of the first handwheel the first nut was screwed up and the plates were compressed between a collar on the back end of the arbor and the bottom of the second nut, which projected beyond the face of the first. If the clutch were running and one wished to release it, it was only necessary to hold the second nut, preventing it from rotating. As soon as this was done it commenced to screw itself up outside of the first nut and released the plates. A multiple plate clutch to be released while in motion could, of course, easily be made with a toggle, but the screw had some advantages and gave great power.

Dr. Hele-Shaw then referred to the multiple plate clutch with which his own name was associated. It had been invented some seventeen or eighteen years ago, and was the result of an attempt to combine the advantages of a cone clutch with those of the Weston clutch. A disadvantage of the flat-plate clutch was that if it once got overheated the plates buckled, and one could then not do much with it. The corrugated plates in the Hele-Shaw clutch were found not to lose their shape, no matter how great the heating. As was generally known the corrugations of the various plates of the clutch were identical and the plates of uniform thickness over all parts when corrugated, being pressed cold. As the outside of one corrugation fitted inside the superposed one, it was shown by means of a geometrical figure that a clearance was left between the outside of the apex of one corrugation and the inside of the apex of the next, and also between the flat parts of the plates. Great power was obtained owing to contact being made only on the coned surfaces, and the spaces left allowed of the circulation of lubricant. Considerable difficulty had at first been experienced in manufacturing the corrugated plates, and ultimately it had been found necessary to employ a series of five dies for the drawing operation. Dr. Hele-Shaw then referred to the coil clutch which was the invention of his brother, Mr. Edward Shaw, and which he and his brother had described in a paper read before the British Association in 1888. This form of clutch had been developed up to very large sizes, as much as 8,000 h.p. being transmitted by it in rolling-mill installations. If the clutch had a defect it was, perhaps, a little fiery.

In the second lecture, on the 8th inst., Dr. Hele-Shaw began by reference to some examples of magnetic clutches. These could be divided into true magnetic clutches and clutches which were really friction clutches and should be called friction clutches magnetically operated as the magnetic attraction was employed to get the pressure which in other cases was obtained by toggles, screws, &c. The Igranic was an example of this latter class. Two discs, one of which carried a coil energised from slip rings, were attracted together, but the actual driving effect of the clutch came from the friction between two surfaces. Clutches of this class, in their simplest form, tended to stick when de-energised, owing to hysteresis, and to enable them to release quickly springs tending to separate the two surfaces were fitted, or a thin layer of fibre was placed between the surfaces, preventing true iron to iron contact. Friction clutches of this type had advantages in their ease of control and in the

fact that they could easily be operated from a distance. A very interesting example of a magnetic clutch was furnished by the Daysohm.* In this case the sticky effect due to hysteresis was got over by fitting a demagnetising coil. In all there were three coils in the clutch: (*a*) the main magnetising coil; (*b*) the demagnetising coil; and (*c*) a coil enabling variations of power transmission to be perfectly under control. The clutch was particularly intended for use in connection with electric arc-welding plants, and the third coil—which operated in terms of the load—caused the clutch instantly to slip in cases of rush of current and so protected the generator. As a final example of a friction clutch operated other than mechanically, an example was shown of a Hele-Shaw clutch operated by pistons under oil pressure and used in aircraft. This was not to be described as a hydraulic clutch. It was merely a friction clutch operated hydraulically.

The principles of true magnetic and hydraulic clutches could easily be illustrated from the simple wooden model of a friction clutch previously described. If the horizontal sliders at the sides were removed and a coil were placed around the vertical slide, which in a practical case would, of course, have to be made of iron, one had a simple form of a true magnetic clutch, the operation of which depended only on the magnetic effect, there being no contact, and consequently no friction, between the moving slide and the coil. The principle of a true hydraulic clutch would be illustrated by letting the vertical slide represent a piston working in a cylinder containing liquid. Slipping of the clutch could be arranged for by fitting a valve through which the liquid under pressure could be allowed slowly to escape.

The concluding part of the lecture was devoted to a brief consideration of friction. Dr. Hele-Shaw said that in his Cantor Lectures on "Friction" of thirty-three years ago he had said that friction between two surfaces in contact was due to the displacement of particles on the surfaces, either breaking them away or bending them over and distorting them. In this particular he was afraid his present lectures must be described as his "Recantor" lectures. It was now believed that when two surfaces were in contact a certain number of particles of the surfaces actually touched each other, and that the friction effect was due to the attractive force existing between these particles. If, of course, very rough surfaces were rubbed over one another bits were knocked out and more work was done; but this was not true friction, which was, as he said, now believed to be due to the mutual attraction of particles of matter. It was generally known that this attraction could be shown directly if true surfaces were placed in contact. For instance, eleven copper cubes, the whole weighing 98 grammes, could be made to hang one from another in a vertical string. This phenomenon was not due to any sucker effect, but was to be explained purely by molecular attraction. Laplace had calculated that this effect could not be detected over a greater distance than 5 cms. $\times 10^{-7}$ cms., which was about $\frac{1}{2,000,000}$ of an inch. In the case of water it was calculated that what was now called the *intrinsic pressure* was about 11,000 atmospheres, or, say, 80 tons per square inch. That was the pressure necessary to alter the volume of water, not to alter its shape.

Applying these ideas to friction clutches it was not difficult to see that one had great possibilities of transmitting force. With two surfaces in contact, it was clear that increase of pressure increased the number of particles which were touching each other and so increased the friction. In metal to metal clutches it was necessary to use dissimilar metals in contact to prevent seizing. The reason of this was now thought to be that the particles in contact became liquified and if they were of similar metals they fused together and locked the clutch. The practical application of friction in the case of clutches had been greatly facilitated by the invention of Ferodo, which was a process not a material. The inventor, **Mr. Herbert Frood**, had scientifically investigated the question of the production of friction brake fabric for the last twenty-five years, and had produced most valuable materials. One of these consisted of asbestos interwoven with brass or copper wire. The asbestos was able to stand the heat, generated in a clutch, without injury, while the wire bound together the short-fibred asbestos and also served to conduct away the heat from the rubbing surface. Other Ferodo fabrics were made of cotton impregnated to give wearing properties and resistance to heat. Dr. Hele-Shaw was now convinced that the correct way to use friction surfaces in a clutch was dry, as was done with Ferodo, although the friction clutch which bore his own name was lubricated. In that clutch a certain time elapsed while the oil was rubbed out from between the surfaces. This certainly had an advantage in preventing the clutch from being fiery. In connection with this rubbing-out of the oil film, Dr. Hele-Shaw mentioned the Michell bearing as illustrating the fact that with suitable arrangements, the oil film never could be rubbed out.

Leaving the subject of solid friction, the Doctor then exhibited a small electric motor as an example of a true magnetic clutch, a clutch which did not depend in any way on friction between surfaces. The arrangement had not been much used in practice. One required a separate exciter and, what in many cases was vital, if there was no motion there was no clutch effect. Examples were then considered of true hydraulic clutches. Many hundreds of these had been patented, but up to the present none had become commercial and in general were useless. Usually they consisted of some form of rotary engine or pump, and while many worked well at high speed, they were nearly all bad at low speed or high pressure owing to internal leakage. In most cases with external leakage the clutch would gradually peter out. These clutches depended for their driving power on viscosity and he wished to take the opportunity of saying that he recanted all he had ever said in the past about fluid friction. In the sense usually understood there was no such thing. The force necessary to drive a fluid through an orifice was, he now believed, due entirely to the impinging of the particles one on another, and to transference of energy between them and this property was called "viscosity." The idea that there was any friction between one particle and the next was incorrect. It was remarkable that Sir Isaac Newton had foreseen this, our latest idea in reference to fluid friction. Newton had said "the resistance of water rises primarily and almost entirely from its *vis-inertia*." A hydraulic clutch therefore operated, by virtue of viscosity when it was transmitting power but at the same time slipping, and by the property of practical "incompressibility" when it was locked.

THE EXAMINATION OF MATERIALS BY X-RAYS.

(*Concluded from page* 611.)

In concluding our notice of the general discussion on "The Examination of Materials by X-Rays," held by the Faraday Society and the Röntgen Society on April 29, we pass to contributions affecting the photographic problems of X-ray examination, and we mention in the first instance the communication on "A Method of Testing an X-Ray Tube for Definition," from the Hadfield Research Laboratory in Sheffield, presented by Mr. J. Brooksbank, B.Sc., A.R.C.S. The focal spot, Mr. Brooksbank pointed out, is never a point, but occupies a certain area, and the shadow can hence not be very sharply defined. In metal work the selection of a tube of very fine focus would be of little use, since the effects of secondary radiation would mask the extreme sharpness of the shadow produced in the radiograph. Moreover, the life of a target was generally longer with larger focal spots. Definition must also be taken into account, and Mr. Brooksbank described how this could be effected. The size of the focal spot could sometimes be ascertained by visual inspection; but with hot cathode tubes that was almost impossible. The size of the pitted area of the target roughly indicated the size of the spot. Coolidge had obtained a radiograph of the spot by the pin-hole method. An idea of the definition could be obtained by taking a radiograph of a wire gauze of fine mesh (45 to the inch) at a distance of about 50 cm. from the spot; the spacings of the wires were irregular, however, and with elliptical focal spots the shadows might be distinct in one direction, but not at right angles to that direction. Moreover, sometimes reversal effects were observed. They had therefore used two uniform wires mounted parallel to one another in the same horizontal plane and to the plate; the distance between plate and focal spot was kept at 50 cm., and the wires were, in taking a series of radiographs, moved further and further away from the plate. As this distance increased, the shadows become less distinct until, in the "critical" position, the wires could not be seen on the radiograph; that critical distance was adopted as a measure of the definition of the tube.

In his research Mr. Brooksbank studied the shadows given by one wire or by two wires with two sources of X-rays, line sources and circular sources, and determined the intensity of the radiations produced when the distance of the plate from the wires was changed. As each wire received illumination both normally and from the right and left (as would be the case with any source of light of some area, not merely a point) the shadows were diffused, and the distance between the most intense shadows changed with the position of the wires. Comparative tests were made with a Nernst lamp and two pins. With a circular source the critical position was more difficult to decide than with a line source; yet the position could be determined within 2 cm. or 3 cm.; from these measurements the area of the focal spot could be deduced. For practical tests Mr. Brooksbank proposed to find by trial the critical position; he would then increase the distance of the wires from the plate slightly, and take radiographs; if the two shadows were separated by a strip of greater intensity than the shadows, the tube satisfied the requirements. Exposures of a few seconds would suffice; the definition would come out worst when the wires were at right angles to the line joining the target and cathode of the tube, and the examination might hence be made with the wires in that position.

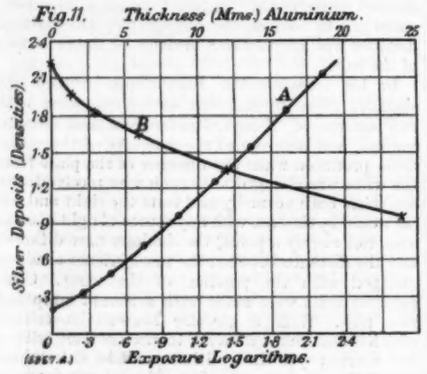
Major C. E. S. Phillips then demonstrated how they had put this method to practical use in the War Office X-Ray Laboratory. The apparatus exhibited could hardly be more simple. There is a plate carrier into which the plate is pushed from the side; the plate is covered by a screen which is provided with a circular window. A ring frame attached to a stand holds the two wires, really fine needles, 0·2 mm. apart; with the aid of a kind of a sliding cam the frame is fixed in one of three positions, at 15 cm., 10 cm., or 5 cm. above the window. Radiographs are taken in these three positions, and the wire shadows will come out more or less sharp. Series of three radiographs were exhibited to exemplify how the apparatus is used for estimating the definition; with gas tubes, Major Phillips mentioned, the wires generally were not visible at all on the radiographs.

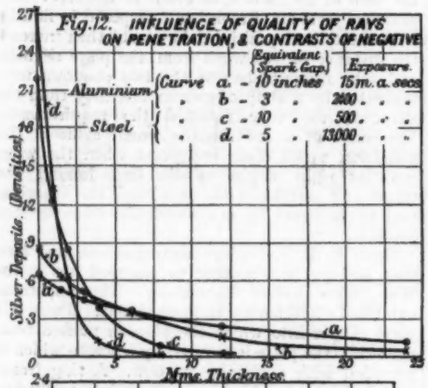
Photographic Plates, Exposure and Contrast.

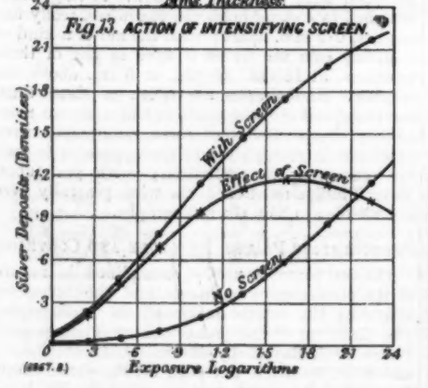
The two papers next read exemplified the nature of the photographic problems and the difficulties attending the interpretation of the radiographs. The first, on "The Behaviour of Photographic Plates to X-Rays," by Messrs. O. Bloch, F.I.C., and F. F. Renwick, A.C.G.I., F.I.C., of the Ilford Research Laboratory, was presented by Mr. Renwick, who gave a brief account of researches, extending over several years, on X-Rays and dry gelatin plates. When the mixed X-rays acted on a plate, he said, the relation between the amount of silver reduced by subsequent development and the quantity of radiation was represented by a curve of the kind of A, Fig. 11; the silver deposits being measured photometrically by determining their opacity logarithm or density ($\log_{10} O = D$); this quantity was plotted against the logarithm of the time of exposure to a constant radiation. Such X-ray curves had a more pronounced foot (curved lower portion) than in ordinary photography; densities, moreover, were in this foot not proportional to the exposure, as was the case with light in the period of under-exposure. A satis-

* See ENGINEERING, vol. cv, page 105.

factory formula, independent of time of development, for expressing the sensitiveness of a plate to X-rays, such as Hurter and Driffield had given for light effect, had not yet been evolved; classification of plates relying on the straight line portion of curve (ignoring the foot) were undesirable as bearing little relation to practice, whilst speed numbers depending entirely upon the foot would possess a real value. Those points were not always heeded, however. When the rays first passed through some material before reaching the plate, selective absorption of the longer waves took place,







and the thicker the specimen, the shorter would be the arriving wave-length; there was, moreover, scattering and transformation of the energy into characteristic radiation. The curve connecting the mass of silver reduced with the thickness of material penetrated differed hence from that found for varying the time of exposure to the same radiation. Curve B, Fig. 11, gave such a curve for aluminium. After a fair thickness had been penetrated the curve became inversely proportional to the thickness; to reach that shape early, however, *i.e.*, at moderate thickness, very short waves had to be adopted for metals of high atomic weight. Much depended upon the developer; on curves exhibited metol-hydroquinone sodium-carbonate proved a faster developer than pyro-soda, but the increase in rapidity was not the same on different types of plates. The duration of the development did not affect the character of the curve.

The influence of the hardness of the rays was shown in Fig. 12 for a series of steps of aluminium (*a*, *b*) and of steel (*c*, *d*), *a* and *c* representing hard rays, *b* and *d* soft rays. The spark gaps used were of 10 in., 5 in., 3 in. respectively and the currents of 3 milliamperes, 6 milliamperes and 9 milliamperes; the exposures (in milliampere-seconds) are marked on the diagrams. The curves well indicated also that a far greater range of contrast could be

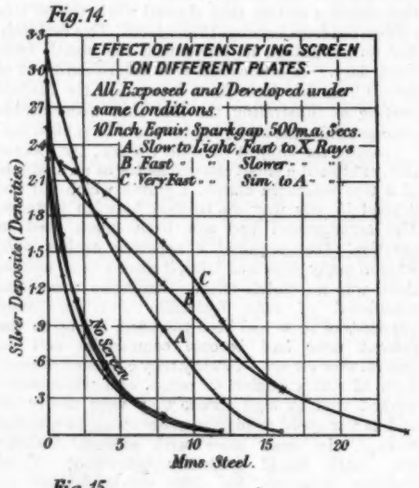
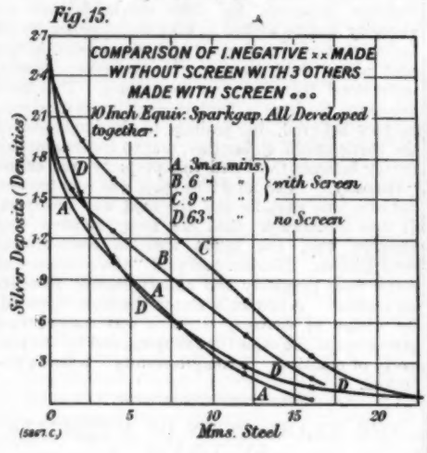
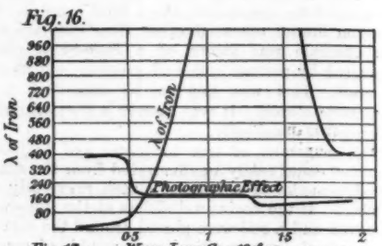
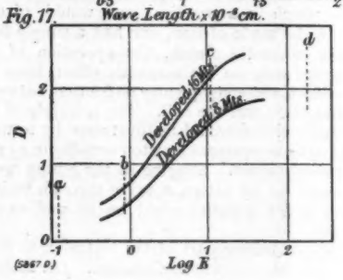


Fig.14.
EFFECT OF INTENSIFYING SCREEN ON DIFFERENT PLATES.
All Exposed and Developed under same Conditions.
10 Inch Equiv. Spark gap. 500 m.a. Secs.
A. Slow to Light, Fast to X Rays
B. Fast " " Slower " "
C. Very Fast " " Sim. to A " "
No Screen.
Silver Deposits (Densities).
Mms. Steel.



obtained with steel than with aluminium; in the case of steel a wide range of intensity should evidently be considered to obtain the full characteristic curve; with the exposures used only the foot had been utilised. To get good contrasts with thick specimens of dense materials both the exposures to hard rays and the developments should be of long duration. Even with the hardest Coolidge tubes (spark gap 15 in.), however, and with very long exposures, 2 in. of steel seemed to be the limit of penetration, and they had hence tried to improve the sensitive materials, turning first to fluorescent intensifying screens. In Figs. 13 and 14 the effects of using commercial calcium tungstate screens were illustrated, the screen being in contact with a plate exposed to increasing doses of radiation; three different plates and various thicknesses of steel were used in Fig. 14. The shape of the curve varied with the ratio: sensitiveness to light to sensitiveness to X-rays, and it would be seen that, in Fig. 14, curve A (slow to light) was convex, B (fast) fairly straight, and C (very fast) concave to the ordinate. Fluorescent intensifier screens not only reduced the time of exposure, but they also increased the contrast, as Fig. 15 further showed. In normal X-ray work (and to a lesser degree also with intensifying screens) the silver deposits produced under the thicker parts of a dense object represented exposures falling within the foot of the curve. The tangent to that curve at any point was a measure of the degree of contrast at that point, and it was obviously not possible to secure good contrasts throughout a negative, unless the quantities of radiation were all sufficiently great to reach values well above those comprised with the shallow part of the foot. Failure to comply with this requirement was the chief reason of the difficulty of bringing out very shallow defects in a thick piece of shell. Unfortunately even the best commercial intensifying





screens were granular and apt to mask fine detail in the radiogram. There was also a very great difficulty about securing good contact between plate and screen, and Mr. Renwick hence doubted the advisability of using separate fluorescent screens in cases where fine definition was essential. Though silver bromide was itself faintly fluorescent to X-rays, there seemed to be little prospect, so far, of making ordinary silver bromide dry plates much more sensitive. Some plates contained fluorescent substances or materials emitting secondary rays under very penetrating X-rays; most of these substances were either injurious to the silver bromide, or were difficult to incorporate in the emulsion. Mr. Renwick thought, however, that success might be achieved.

Dr. R. E. Slade, of the British Photographic Research Association, hardly did himself justice in his paper on "Contrast and Exposure in X-Ray Photography through Metals." Considering the efficiency of the photographic plate, he said, that the experiments of Barkla and Martyn (1913) were the only ones available showing the relation between photographic effects and wave-length of the radiation (characteristic K radiations of metals), and their curves were not very accurate. Dr. Slade did not add, however, that his very interesting conclusions, which appeared to be little more than mathematical deductions, were in agreement with investigations by Professor Bragg—who had drawn attention to Dr. Slade's paper—and others. The developed negative, Dr. Slade pointed out, left the glass covered with a coating of gelatin containing finely-divided silver. Barkla's curve (Fig. 16) indicated that the absorption due to the silver bromide increased with decreasing wave-length first in a small step, probably due to the bromine, and then in a larger step, due to the silver. If j_o, j_t and j_a represented respectively the intensities of the incident, transmitted and absorbed rays, the ratio j_t / j_o was the transparency (and its reciprocal the opacity), and Dr. Slade showed that when the rays entered the film directly (without having first passed through metal), $j_t = j_o \cdot 10^{-D}$ where D was the density of the silver in the film, in the sense of Hurter and Driffield (1890), who meant by density the number of particles of a material spread over unit area, which was a measure of the chemical work done by the light. The

density varied with the exposure E (the product of intensity and time) according to $D = A + B \log. E$, where A and B were constants. The two curves, Fig. 17, exemplified the relation between D and log. E for exposures of 8 minutes and 16 minutes. Both were practically straight lines between b and c; between a and b was the region of under-exposure, between c and d the period of over-exposure, and at c the exposure would, on an ordinary plate, be about 300 times as long as that at b. These curves held in the first instance for ordinary light; Tugman (1915) and Hodgson (1917) had proved that the relation between D and E was the same for X-rays. As it was almost impossible to print from an over-exposed X-ray negative, most X-ray photographs were taken on the under-exposure portion of the curve.

Dr. Slade then considered the case when the X-rays first traversed a thickness of d cm. of a metal of absorption coefficient λ — this designation of the absorption coefficient by λ in problems affecting wave-length is regrettable, but common practice—before entering the film of thickness t and absorption coefficient λ_1 (silver bromide). Both λ and λ_1 varied with the wave-length; but except at points where there was selective absorption, λ would be equal $a\ \lambda_1$ (where a was a constant), and in that case the equation $\lambda\ d = 1$ would hold. That meant that the photographic effect for a metal thickness of 2 cm. would be maximum if $\lambda = 0{\cdot}5$, and with most metals the radiations to be used for examination should hence be exceedingly hard (*i.e.*, of short wave-length). The remarkable change of the absorption coefficient λ with wave-length was exemplified by the following table, which gives the λ for aluminium and iron, and for iron also by Fig. 16:—

Wave Length in 10^{-8} Cm.	λ Aluminium.	λ Iron.
1.95	238	518
1.80	192	527
1.66	140	2460
1.55	128	2100
1.45	106	1740
0.72	8.3	262
0.56	6.7	136
0.50	4.3	86
0.48	3.3	66

In order to attain the greatest contrast, that is, the greatest density difference $D_b - D_a$, where D_a marked the density at any spot where the rays had passed wholly through metal, and D_b at a spot where they had traversed a blowhole, the exposure should be on the correct exposure portion between b and c, Fig. 17). But with the thick emulsions of X-ray plates the negatives would then be far too dark for printing, and the top of the under-exposure portion should hence be utilised. Since, further, the absorption λ was great for long waves (soft rays), soft rays would give better contrasts; yet we had to use hard rays to shorten the exposures, and Dr. Slade showed that the contrasts were sufficiently great also with hard rays. Finally Dr. Slade referred in particular to the case of iron which [compare the λ curve of Fig. 16 and the table] had very high absorption values for wave-lengths greater than $0{\cdot}5 \times 10^{-8}$ cm., thus requiring long exposures. Yet thickness differences of 0·005 cm. should be quite perceptible, especially, *e.g.*, with rays like the K radiation of nickel, $1{\cdot}66 \times 10^{-8}$ cm. As, however, nickel anti-cathodes were not very suitable for photography through iron, anti-cathodes of tungsten or platinum and wave-length of 0·3 cm. or $0{\cdot}45 \times 10^{-8}$ cm. were preferable; large spark gaps would be required. In the case of tungsten the K radiation (the only one which mattered for these purposes) had with 68,500 volts a wave-length of $0{\cdot}18 \times 10^{-8}$ cm., which became reduced to 0·12 of the same unit at 100,000 volts, thus being fairly steady. In the case of molybdenum the wave-lengths fluctuated very much more.

The important point in these conclusions was that the contrast in photography through, say, 1 cm. of iron did not depend upon the absolute thickness of the iron, but that the effect was almost entirely due to the hardest rays, though it would be greater with relatively soft rays. That seemed contrary to experience. The explanation was this, Dr. Slade mentioned. Supposing there was a blow-hole of 1 mm. in 1 cm. of iron; a good contrast could easily be obtained. If that same bubble were in a specimen, 6 in. in thickness, the same contrast could, with the same tube voltage, be obtained by increasing the exposure many thousand times, the function being exponential. In practice we used harder rays to reduce the exposure period; but the contrast was then very much less distinct. We do not know how far these arguments are influenced by the fundamental assumption that the photographic effect depends upon the product: intensity multiplied by time of exposure (milliamperes by seconds), and not upon each of the two factors independently, or that in other words, weak intensity with long exposure has the same effect as strong intensity with short exposure. Photographers accept that assumption—with reservations—and like them, X-ray workers rely on photographic densitometer tests. But the principle is certainly questionable, especially as regards X-rays. The rays are not homogeneous; they probably fluctuate in hardness from moment to moment and with the hardness varies the scattering which plays an important, yet quantitatively unknown, part. Dr. Slade considers that possible deviations from the milliampere-second rule would hardly affect his conclusions. Mr. Renwick referred to this difficulty in the beginning of his paper, but he expressed exposures in the customary way in milliampere-seconds.

In the general discussion Mr. A. A. Campbell Swinton, F.R.S., remarked that the X-ray bulb problem should be tackled on engineering lines. He did not wish to be limited to milliamperes, but wanted kilowatts. That was not an impossibility. In radiotelegraphy valves had been used as detectors; now they served as oscillators. The trouble with glass tubes was that strong currents melted them; with steel tubes the occluded gas gave trouble, unless the whole tube were evacuated while red hot. But the interior of the metal tube might be enamelled as in Gaede pumps; such tubes, of 2 ft. or 3 ft. diameter, for 10 kw. or 15 kw. would not cost so very much, and we did not know what they might be able to do. Referring to this, Captain Kaye stated afterwards that Coolidge had, in his especially-cooled tubes, gone up to 14 kw. (20 h.p.) before the war, but the war had forced other work upon him; metal tubes had been introduced by O. Lodge 20 years ago, and all-metal tubes provided with porcelain insulators had been used on the Continent by Zehnder and by Siegbahn. Most experimenters seemed, however, to have dropped the metal tube eventually. Captain H. G. Jackson, for some time Ordnance Inspector at Sheffield, said they wanted some means for rapidly examining heavy ordnance forgings made of nickel-

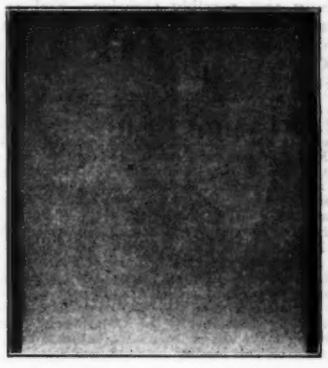


FIG. 18.

FIG. 19.

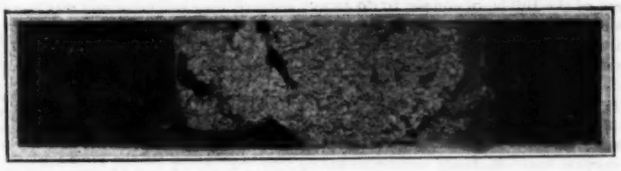


FIG. 20.

FIG. 21.

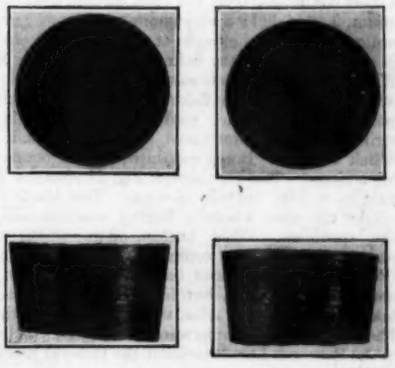


FIG. 22.

chrome steel. That steel showed typical flaws which so far they could only discover during turning; to make fairly sure of having their parts of the required strength, they had to allow for a very large margin of safety. Hence some means for rapidly testing assembled parts would also be most valuable. Mr. S. A. Pollock of the Postal Department, remarked that the Post Office was very much interested in the possibilities of X-rays; there were many baffling problems—the study of the corrosion and uniformity of cable sheath of lead, of their steel armouring, and of their insulation, among others—which the X-ray tube could help to attack, and they were going to try this method; it had already proved useful in examining gutta-percha for adulterations.

The few photographs, which we finally add, will further exemplify the valuable services that the X-rays can render to the engineer and metallurgist. Figs. 18, 19 and 20 explain the examination by Mr.

FIG. 23.

H. S. Rawdon, of the United States Bureau of Standards, of two pieces of steel, one suspected of being "flaky"; the point was mentioned by Sir Robert Hadfield in his introduction. The latter specimen was cut transversely out of a finished gun forging, of a steel containing 0·37 per cent. carbon, 0·01 chromium, 2.85 nickel; a very similar specimen gave a uniformly grey radiograph, the suspected specimen, ⅜-in. thick, showed the flake visible in the line XX. When the specimen was sawn open along this line and broken, the large flake of Fig. 20 (an ordinary photograph) became visible. A similar, very striking case is illustrated in Figs. 21 and 22, which Professor Bragg exhibited in the course of his address. The photograph Fig. 21 shows a bad flaw in a ⅜-in. turbine casting. The black ring marks the spot where a button was cut out of the specimen. This button, ¼in. thick, was photographed in the ordinary way in four views (Fig. 22). The top and bottom of the button do not display any flaw, but in the two other views, taken from opposite sides, the flaw is very distinct. These X-ray photographs were taken by Dr. Coolidge in the Research Laboratories of the General Electric Company.

Fig. 23, from the same source, refers to the improvement of high-conductivity copper effected by boron suboxide. Cast copper is frequently full of pores and blowholes; ordinary deoxidisers added to the copper remove the gases, but alloy with the metal and lower its electric conductivity; the boron suboxide of O. Weintraub deoxidises the copper without combining with it, and tons of copper are now cast by the General Electric Company with boron. Fig. 23 shows the "unboronised" copper. The radiograph of the "boronised" copper, which Professor Bragg placed next to our photograph, was merely a spotless grey square. Professor Bragg further showed radiographs of some good and some bad welds; they were quite sufficiently plain to let the operator recognise the success or failure of his work, but they might not come out well in our reproduction.

Radiographs of welds and of other specimens and X-ray apparatus, &c., we should not omit to mention, were also exhibited by the British Thomson-Houston Company, by Messrs. H. Cox and Co., and by Messrs. Newton and Wright. One of the exhibits of Messrs. Watson and Sons, to which we have already referred, was their stereo-fluoroscope, an attachment to X-ray outfits, especially designed for the examination of materials and general objects the structure of which appears in stereoscopic relief.

NOTES.

THE ELECTRICITY SUPPLY BILL.

THE Electricity Supply Bill, the Second Reading of which was taken in the House of Commons on the 14th inst., in the main follows the recommendations of Sir Archibald Williamson's Committee. The Report of the Committee of Chairmen to which we made reference in our first leader of last week, has, apparently, to a very large extent been ignored. This is satisfactory. If we are to have a national electric supply system it is all to the good that as far as possible local experience and knowledge should be utilised, and this aim should be achieved in the constitution of the District Boards. The general proposals of the Bill are for the constitution of a body of five Electricity Commissioners to be appointed by the Board of Trade. These Commissioners would really handle the whole electric generation and transmission business of the country, except private generating plants which it is not proposed to interfere with. The Commissioners, by means of local enquiries, would divide the country in areas each of which would be administered, from an electric supply point of view, by a District Board. These Boards would consist of members of local authorities at present supplying electricity, members representing electric supply companies, together with members representing consumers and labour. The Board would take over all generating stations and transmission lines, but would have nothing to do with distribution which would be left in the hands of present supply authorities, which would purchase current in bulk from the Boards. The main object of the Bill is, of course, to do away with the present piecemeal generation and unsuitable in small areas of supply. It appears to promise this from a generating point of view, but it is not clear that technically unsound distribution areas will not be left as at present. This, however, is a matter which may well be left over for the moment. Financially each District Board is to support itself, with the proviso that supplementary assistance may be given from the National Exchequer.

THE JAMES WATT CENTENARY.

This year marks the centenary of the death of James Watt who, born at Greenock on January 19, 1736, died at Heathfield Hall, on the north side of Birmingham, on August 19, 1819. He was buried in the churchyard of the neighbouring parish of Handsworth. Watt is one of the greatest, if not the greatest, name in the history of mechanical engineering, and it is fitting and wise that the anniversary marked by August 19 next should not be allowed to pass without national recognition. Engineers are perhaps too apt to neglect, or forget, the history of their art and the long tale of workers, great and small, who laid the foundations of a science and a practice which have changed the face of the world. Above all is it wholesome to remember the great individual workers whose names stand out above others in the record and which serve as an incentive to a newer age. Watt's achievements and fame stand for a brilliant faculty nurtured and broadened by a lifetime of hard work. The first is a gift of the gods; the second we may all aim at. *Palma non sine pulvere.* Although Watt was a native of Greenock, he spent 45 years of his life in Birmingham, and it was during his association with Boulton in that city that his engine established the position from which it and its successors were to spread throughout the world. This being so, a proposal has been made that the centenary celebrations should take place in Birmingham, and a meeting was held in the Council House of that city on the 8th inst. to consider and adopt the proposal, which had been put forward by a provisional committee of which Mr. W. Mills, M.I.Mech.E., was the chairman. The meeting on the 8th inst., at which the Lord Mayor of Birmingham was in the chair, adopted the proposals of the provisional committee and appointed a general committee to carry them out. This general committee consists of the Lord Mayor of Birmingham, the Lord Provost of Glasgow, the Provost of Greenock, two members of the Birmingham City Council, representatives of engineering and scientific societies, universities, and firms associated with the movement, together with the members of the provisional committee. A further meeting is to be held on the 20th inst. to elect sub-committees and transact other business. The honorary secretary is Mr. R. B. Asquith-Ellis, Chamber of Commerce-building, New-street, Birmingham, to whom enquiries and offers of service should be addressed. The present proposals are for a commemoration service at Handsworth Church, a gathering at Heathfield Hall with an exhibition of relics, addresses and a commemoration dinner. If funds permit it is proposed to establish a James Watt Chair of Engineering at Birmingham University and possibly elsewhere, and to build a Memorial Hall. Towards these objects Messrs. the Birmingham Small Arms Company has promised 5,000*l.* on condition that other sums of like amount are forthcoming.

THE MIDLAND JUNIOR MINING ENGINEERS SOCIETY.—A well attended meeting was held at Sheffield University on May 3 to consider the proposed formation of a Midland Junior Mining Engineers Society. The meeting decided to include mechanical and civil engineers. Professor Fearnsides took the chair. It was unanimously decided to ask Mr. J. H. W. Laverick, of Sheffield, to accept the office of honorary president. Mr. Gerald T. Newbould, of Earl Fitzwilliam's collieries, was elected president for the coming year, and Mr. H. J. Atkinson, of Wharncliffe Silkstone Colliery, near Barnsley, was elected hon. secretary and treasurer. Papers will be read by the members, and it was also decided to endeavour to obtain contributions to the transactions from, and to include as overseas members, students of overseas universities and mining districts.

DETECTION OF OVERHEATED BEARINGS.—Though hot bearings are no longer the probable cause of a breakdown in machinery that the engineer thinks of in the first instance, they still occur and give trouble which an early indication of insufficient lubrication, shaft gripping, dirty bearings, or similar irregularities might easily have avoided. From a paper by Mr. H. T. Pinnock, in the Journal of the Society of Chemical Industry, March 15, 1919, we see that Tonner, in America, first had the idea of painting parts apt to overheat like the axles of railway cars, with some compound which changes its colour when hot and resumes its colour when cold. Such devices would be simpler than the thermoelectric or dilatometric devices proposed for the same purpose, but they do not appear to have found adoption. Pinnock has taken the suggestion up, and he makes use of some metallic iodides well-known for the peculiarity of displaying distinct colour changes with changes of temperatures. In most cases these colour changes are slow and not sufficiently striking. Pinnock found two compound iodides most suitable, both of which frequently serve for demonstrations: First the copper-mercury iodide, $Cu_2I_2 . 2HgI_2$, recommended by Tonner; this substance turns from vivid scarlet-vermilion at ordinary temperature to chocolate-brown at 60 deg. or 70 deg. C.; secondly, the silver-mercury iodide $Ag_2I . HgI_2$, which changes from pale lemon-yellow to carmin-red at 90 deg. or 100 deg. C. Pinnock further observed that a mixture of these two double iodides, in the proportions of 85 to 15, was more sensitive than either of the two compounds; this mixture has vermilion colour and turns black when hot. The preparation of the detector chemicals is not difficult. For the first, 350 grains of cuprous iodide, 910 grains of mercuric iodide and a little water are ground together in a mortar, and the paste is dried and powdered. Or the mercuric iodide is dissolved in an aqueous solution of potassium iodide and then precipitated with either copper sulphate or (for the manufacture of the second compound) with silver nitrate. In these latter cases the precipitates have carefully to be washed with water to remove the solvent and impurities. The compound has to be provided with a suitable medium; white shellac solution in alcohol answers for this purpose; the medium which is used for applying aluminium paint is said to be still better. On the bearing a ring of white zinc paint is first painted, and a bull's-eye of the compound then filled in, and covered with a varnish to keep off the dust. In the case of a journal two rings of white paint are drawn round the shaft with an intermediate ring of the yellow or red iodides; by contrast with the white the colour and its change can be seen at considerable distance. As soon as any change is noticed, the engineer knows that there is something wrong. Mr. Pinnock has had some of these detectors in use for ten years, and they are still doing their duty although the varnishes be first mixed with them were not perfect and had to be renewed. It is obvious that the device will also be useful on the feeder and exhaust pipes of gas producers and engines and on the various towers with which the chemist works. In some cases, of course, paints would be required which only change colours at higher temperatures; there is a field then for further investigation.

INDUSTRIAL NOTES.

LORD DURHAM gave evidence at the sitting of the Coal Commission held on Wednesday, the 7th inst., and stated that he owned the coal under 12,411 acres of land in the County of Durham. All this coal was let and was being worked, or would be worked shortly. For at least 100 years prior to 1896 he and his predecessors were amongst the largest colliery owners in the County of Durham. They not only held leases of coal belonging to others, but developed and worked a large portion of their own coal. In 1896, he ceased to be a colliery owner by selling to a company formed by Lord Joicey all his leasehold collieries and all his plant and machinery at all his collieries, both freehold and leasehold, and at the same time leased to this company for sixty years the freehold coal worked by him. The tonnage rents payable by the company for this coal were the same as those then being paid by him to the Ecclesiastical Commissioners for their immediately adjacent coal. Neither he nor his father, who succeeded the first Earl of Durham, ever prevented coal from being worked by refusing to lease. One lease still current was granted by his father in 1867. Of the 12,411 acres of coal owned by him and leased to colliery companies, his title deeds showed that about 6,000 acres were bought within the last 100 years, 4,000 acres were bought between 1720 and 1820, and the remainder was ancient land owned by the Lambton family. The title deeds showed that the lands acquired since 1720 included the coal. Apart from the purchases referred to, he or his predecessors had purchased over 1,250 acres of freehold land within the last 200 years, from which the coal was expressly excluded. In 1913, the royalty rents, on 2,338,604 tons, worked out at 5·424*d.* per ton; the underground wayleaves, shaft rents and surface wayleaves, on 970,113 tons, were 1·056*d.* per ton. The corresponding figures for 1918 were, on 1,526,315 tons, 5·6*d.* per ton, and on 670,793 tons, 1·083*d.* per ton. In addition, he was entitled per year to 1,500 tons of coal free for his own use and that of his employees. At present, the State charged on the amounts he received, mineral rights duty at 1*s.* in the pound, income-tax at 6*s.* in the pound, super tax at 4*s.* 6*d.* in the pound; out of the balance, 8*s.* 6*d.* in the pound, he had to bear the expense of supervising the working of the mines, of collecting the rents, and legal expenses. The fact that he owns this coal and receives rents for it induced him and his agent constantly to watch and see that all the available coal was worked.

Lord Dynevor said his estates in Carmarthenshire and Glamorganshire covered about 9,300 acres. There was coal under about 8,720 acres. The average annual output on his estate during the years 1916 to 1918 was 394,420 tons; the average royalties for coal for the same years was 4·745*d.* per ton, being on a fixed basis. There was a small area of 425 acres with one seam only, which had been sublet by one colliery to another, in which the royalty was one-twelfth of the selling price. The average annual income from royalties for the years 1916 to 1918 was 7,543*l.*, and from wayleaves 1,778*l.*, without taking into account the mineral rights. His family bought the larger part of the present estate in about 1600, and there had been various additions by purchase, at a later date.

Lord Dunraven next stated that the total acreage of the Dunraven estate was 26,443 acres; that of the coal area was 17,602 acres. The output of coal for 1918, which was about an average year, was 2,318,200 tons. The average royalty on the fixed and sliding scale was 6*d.* per ton. Only one colliery was on the sliding scale and there the scale worked out, in 1918, at 11*d.* per ton. The royalties and wayleaves in 1918 yielded 58,854*l.* in royalties and 5,516*l.* in wayleaves. The bulk of the Dunraven estate was purchased by the Edwin family between 1684 and 1685.

At the sitting of Thursday, the 8th inst., Mr. Warren, the agent for the Duke of Hamilton, said his average coal output per year for the last ten years was 4,272,000 tons, the royalties on which averaged 6·391*d.* per ton.

The Duke of Northumberland, who was then called, stated that the acreage of his proved mineral rights was approximately 244,500 acres. There was evidence to show that coal was worked from part of the property as long ago as the thirteenth century. For the last six years the average annual output had been 1,950,044 tons. The average royalty per ton for the same period had been about 6·77*d.*; for the last year it was about 9·25*d.* By deducting excess minerals rights duty, mineral rights duty, income-tax and super tax, the 9·25*d.* was reduced to 3·4*d.* For the last year, the results were as follow: Gross income, 82,450*l.*, less excess mineral rights duty 16,407*l.* and less 42,153*l.* income-tax, mineral rights duty and super tax, leaving 23,890*l.*

The Marquess of Londonderry said he was the owner of minerals proved to exist under about 5,808 acres in the County of Durham and he also carried on the business of a colliery owner in that county. The royalties payable to him were fixed tonnage royalties; they varied with the different coal seams, the average highest of any one mining property being 5·5*d.* per ton, and the lowest 3·25*d.* per ton.

After the Earl of Stafford had given particulars of several comparatively small collieries, Mr. J. Tryon, trustee of the Earl of Dudley's estates, said that the estates of about 12,000 acres were in South Staffordshire and East Worcestershire; they had been held by the family for many centuries; and up to the present time the whole of the products, including royalties, had been expended in development.

Lord Tredegar, at the sitting of Friday, the 9th inst., said the approximate extent of his estates was 82,000 acres, of which 18,800 acres contained coal. The average annual output for the six years ending December 31, 1918, was 3,564,000 tons. During the same period, the average royalty on coal he received was 4·997*d.* per ton. The average annual income in respect of royalties and dead rents on coal, still for the same period, after allowing for concessions, was 74,397*l.*, and the average receipts in respect of wayleaves were 9,430*l.*

Lord Bute, who followed, said that his average holding of land was 128,582 acres, and of proved mineral rights 48,878 acres. The average annual coal output for the six years down to December 31, 1918, worked out at 3,242,000 tons. The average royalty, before deduction of mineral rights duty, increment value duty, income-tax and super tax, was 6·42*d.*, in regard to fixed royalties payable on 85·31 per cent. of the output; and 1*s.* 5·92*d.*, in regard to sliding scale royalties payable on 14·69 per cent. of the output. The average royalty, taking both fixed and sliding scale royalties, was 8·14*d.* The average annual income, without deduction of any of the above-mentioned taxes, was, from royalties 109,277*l.*, and from wayleaves 6,495*l.*

Mr. J. D. McLauchlan, mining engineer, Edinburgh, then said that if nationalisation was decided upon, each colliery would have to be valued separately, owing to the variations in the conditions of life of each. The same applied to individual royalties. He thought the nationalisation of the mines and minerals would be a step in the wrong direction. It would do away with all incentive to enterprise. But he saw no objection in mineral owners being controlled by the State to a certain extent, in order that our mineral resources should be made the most of and developments properly designed and carried out; in fact, he would recommend that course.

At the sitting of last Tuesday, the 13th inst., Mr. C. E. Rhodes, who said that he had been engaged in mining for 54 years and was intimately acquainted with the coalfields of South Yorkshire, Nottinghamshire and North Derbyshire, stated also that in the greater portion of these coalfields the average royalty was about 5*d.* per ton; in the more recently developed areas the royalty was under 4*d.* per ton. Underground and surface wayleaves were rare. Speaking generally, the royalties in the said coalfields had not materially handicapped or interfered with their full development. There had been a few cases where lessors of small areas had shown an unreasonable attitude, holding up these small areas, and machinery could be established for dealing with these few cases. The same machinery could deal with all existing defects of private ownership. It would be, he added, a national misfortune if the mining industry were closed to private enterprise. He failed to see how State ownership could have done more than had been done by private enterprise in dealing with royalties and with the development of mines. Nationalisation would create a large monopoly; individual effort and initiative would disappear, and there would be no check on the price of coal to the community, as the incentive to practice economy which now followed private enterprise would to a large extent disappear. The State would not obtain the best brains for developing the industry. No system of State ownership could have avoided the risk of flooding the deeper mines except by leaving a barrier.

Mr. T. H. Bailey, Mr. C. E. Forestier-Walker, Mr. T. Vachell, Mr. J. Wallworth gave evidence against nationalisation and Mr. J. Dewrance, chairman of Messrs. Babcock & Wilcox, Ltd., gave examples of boring developments and other work carried out by pioneer companies, and added that nationalisation on any of the terms suggested was incompatible with efficient pioneer work.

INCORPORATED MUNICIPAL ELECTRICAL ASSOCIATION.—This Association states that owing to the difficulties concerned with catering when the Association visits Ipswich on the first day of the convention, it has been necessary to make the dates for the convention Wednesday, Thursday, and Friday, June 18, 19, and 20, instead of the dates previously announced. The Felixstowe hotels have been notified of the alteration. A revised programme is shortly being issued to members.

FLAKES IN ALLOY STEELS.

WITH reference to the discussion by the members of the American Institute of Mining Engineers in connection with papers presented on the above subject during March, as reported in our issue of April 25, page 544, we desire to direct attention to the paper entitled "The Value of Observation in Works Practice," read before the Engineers and Metallurgists' Society, Sheffield, by Mr. H. H. Ashdown, Newcastle-on-Tyne, in November, 1918, in which was embodied a lucid reference to this trouble. This paper was reported in full in the issue of this journal of January 3 last on page 11.

Although, as Mr. Ashdown stated, the root of the trouble was in the steel, as cast, due to the presence of non-metallic inclusions it did not always develop in the ingot form, but more frequently in the forgings subsequently made, owing in all probability to the stresses induced by the forging operations and again to the unevenness of cooling. Where forgings made from these "tender" casts of steels had been placed in a hot annealing furnace immediately after forging, and allowed to acquire a uniform heat and cool down with the furnace, no trace of these defects were to be observed.

The illustrations which were given with Mr. Ashdown's paper were all taken from finished forgings, and it will be observed the defects were almost entirely of a circular formation. Had these defects occurred in the ingot form, on forging, the shape would have been much distorted and their final shape would have been anything but circular. It was further pointed out in the paper referred to that once these miniature ruptures had occurred, no form of subsequent heat treatment could cure these defects.

Although these defects do occur in badly made nickel steels, they are apt to be more prevalent in nickel chrome steels, and in the latter their origin has been traced to the presence of oxides of chromium.

BRITISH STEEL PRODUCTION.—We have received from the National Federation of Iron and Steel Manufacturers, the following table showing the production of steel ingots and castings in the United Kingdom during the year 1918, according to the returns received direct from the steel manufacturers:—

Production of Steel Ingots and Castings in 1918.

District.	Bessemer Acid.	Bessemer Basic.	Open-hearth Acid.	Open-hearth Basic.	Total.
Cleveland ..	—	200,873	214,945	1,108,625	1,524,443
Cumberland and North-West Coast	225,983	—	159,901	—	385,884
Northumberland and Durham ..	—	—	372,821	104,919	477,740
South and West Yorks.	162,938	98,512	741,396	293,021	1,295,867
South Wales and Mon. ..	399,434	—	950,271	708,202	2,057,907
North Staffs. and Salop ..	—	41,436	—	133,738	175,174
South Staffs. and Warwick	—	157,504	31,352	149,889	338,745
South Lancs. and North Wales ..	—	—	97,480	634,322	731,802
Scotland ..	—	60,325	1,332,970	487,475	1,889,770
Lincolnshire ..	—	—	—	298,235	298,235
Other districts	—	—	—	5,989	5,989
Total ..	788,355	567,650	3,901,136	3,924,415	9,181,556
Electric steel ingots ..	—	—	—	—	103,021
Total ingots	—	—	—	—	9,284,577
Castings, Bessemer and O.H. ..	—	—	—	—	261,950
Castings from electric furnaces ..	—	—	—	—	44,901
Total steel ..	—	—	—	—	9,591,428

THE INSTITUTION OF ELECTRICAL ENGINEERS, SCOTTISH CENTRE.—The summer meeting of this centre will be held at Aberdeen, on Friday, June 6, 1919, when there will be various visits and a lecture by Professor Magnus Maclean, D.Sc., F.R.S.E. The President of the Institution is expected to be present, and to deliver an address.

TRANSATLANTIC FLIGHT.—We are informed that Messrs. Boulton and Paul, Norwich, have officially entered a second machine for the *Daily Mail* transatlantic flight. This second entry is exactly the same type of machine as Messrs. Boulton and Paul entered some weeks ago, *i.e.*, a twin-engined biplane fitted with two "Napier Aero" engines. It will have similar cruising and full speeds of 116 m.p.h. and 148 m.p.h., a cruising range of 3,800 miles at cruising speed, and the power if need be of completing the whole flight on one engine.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The steel works in the West of Scotland continue to be well employed, and the demand for immediate requirements is very good. The only thing which militates against forward business is the uncertainty with regard to selling prices after the end of June. This is somewhat retarding things, but producers considered it necessary to fix a date limit for the current rates in view of the uncertainty of the forward prices of raw material. If the latter could only be approximately gauged then the position would become clearer, and new business would considerably increase, but for the present the conditions are likely to remain without change. New work there is in abundance, but only the most urgent of it is being fixed up meantime. For both ship and boiler plates there continues to be a good steady demand, and the outlook promises very well indeed. Active conditions are general in the sheet mills, and although the recent advanced list of prices has had a tendency to slow down fresh business, there is really no great falling-off in demand. For steel tubes the demand is good, and mills are going well. Export business is gradually getting better, and the prospects in this direction look very satisfactory. Inquiries from the foreigh markets are on a large scale, and it is anticipated that before very long the shipping trade will have increased considerably.

Malleable Iron Trade.—Conditions in the malleable iron works are unaltered, and labour has much to do with the present output. There is an excellent demand for the home market and as order books are well filled, a steady business is assured for some time. The inquiry for shipping lots is good, but as prices are high and supplies a trifle limited, any increase in this direction must be slow. The export price for "Crown" bars is 20*l.* per ton. net.

Scotch Pig-Iron Trade.—A strong demand again prevails for Scotch pig-iron, and the present output is not nearly sufficient to meet the immediate requirements. The ordinary qualities are readily absorbed, and the steel works are getting through as much hematite iron as they can secure. Prices are rather firmer, and hematite is quoted round 9*l.* 5*s.* per ton delivered at the steel works. The export trade is on a very small scale on account of the scarcity, and the rapidity with which the present production is being consumed at home. Inquiries are plentiful, and whenever there is a sufficiency available a fairly good shipping business is likely to be done.

Scotch Coal Trade.—In the Scotch coal trade there continues to be quite a healthy demand and large deliveries are general. The present Government control prevents expansion of business, particularly with regard to shipping, but with the advent of summer weather less house coal will be required, and an increased output of other qualities may be expected. Large consumers, railways, gas works, and other industrial concerns, are taking in large supplies. Prices are unchanged at the controlled rates.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Despite the advance in all classes of pig-iron, buyers are coming forward rather more freely. The explanation is that works stocks are low and that manufacturers are thereby forced on to the market to cover contract requirements. Taken as a whole, the output of basic material does not appear to be in excess of requirements, which, calculated on daily output of finished materials, are heavy. Finished iron is in fairly strong demand, and some of the bar mills are busy. Hematites are offered at 185*s.* 6*d.* and 178*s.* 9*d.* for West Coast and East Coast makes respectively, delivered in Sheffield; Derbyshire foundry, 146*s.*; Derbyshire forge, 144*s.*; bars, 22*l.*; and sheets, 25*l.* A further revision of basic prices is forecasted next month. In which direction this will be is not certain, but the widespread complaint that export trade is being impaired by the present high level of values, will doubtless be taken into consideration. Armament departments have not much work on hand, but this is to some extent counterbalanced by the rush of orders from the shipbuilding yards. Home demands are heavy, and plates, castings, and special tools are eagerly sought on export account. The total of orders already booked will keep departments busy for from three to four months ahead, and orders continue to arrive freely. Coupled with the insistent call for railway material, especially for tyres and axles, this spurt of activity is keeping the rolling mills busily engaged. Forges and foundries have a moderate amount of work on hand. The position in the Siemen's furnaces has slightly improved. A promising feature is the inquiry for motor car steel. Makers of motor vehicles report an extraordinary demand for small pleasure cars. Electric steel is also attracting rather more attention. Some of the edge tool, file, and saw concerns are working extra time to dispose of the increasing volume of business, much of which is on export account, largely to the Colonies.

Hull Coal Traffic.—Only 146,279 tons were taken to Hull last month, as against 201,205 tons in the corresponding month of last year, a decrease of 54,776 tons. From January 1 to April 30 of this year the quantity was 686,482 tons, compared with 859,621 tons in the first four months of 1918.

South Yorkshire Coal Trade.—During the past week the output at the pits has improved. Steam coal is in strong demand by all sections of home consumers. The fact that home industries practically absorb the current output is advanced as the explanation for the continued embargo on Hull traffic. Cobbles, nuts and slacks are in a firm position, contractors taking practically all available supplies. The house coal market is still unable to meet the requirements of consumers. A general shortage of supplies is reported, which would be more pronounced but for the allocation of steam coal for household purposes. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Further rise in values of Cleveland pig-iron have not deterred buyers at all. On the contrary, customers are following the upward movement without any hesitation, and are as eager as ever to place orders. There is now, however, little iron available for sale, most makers having fully disposed of their output to the end of next month, and refusing to commit themselves beyond that date, and customers who have left themselves wholly or partly uncovered for current needs are very awkwardly placed. Forged iron is much less scarce than are foundry qualities and no longer commands the same price as No. 3. Sellers are now prepared to sell forge at a shilling below the No. 3 quotation, but unfortunately for many of the works the inferior quality of iron is altogether unsuitable, and consumers abroad having been accustomed to use foundry kind, are not disposed to entertain offers of forge iron. Exports of Cleveland pig-iron are somewhat better, and should show considerable improvement in the near future as a lot of the iron recently sold to merchants is understood to be for shipment abroad. No. 3 g.m.b. Cleveland pig-iron is now fully 155*s.*, and as a matter of fact, above that figure has been realised. No. 4 foundry is nominally the same as No. 3, but could probably be bought at rather less, No. 4 forge is 154*s.*, and No. 1 is not less than 159*s.*

Hematite Iron.—Makers of East Coast hematite are in an exceedingly strong position, many of them, in fact, being so well sold that they do not wish to enter into further contracts at present. Supply in this branch is even more restricted than is that of Cleveland pig-iron. The very few small odd lots that come on the market are immediately snapped up at high figures, customers outbidding each other to secure them. Nothing under 185*s.* is now named for Nos. 1, 2 and 3, and No. 1 is fully 187*s.* 6*d.*

Foreign Ore.—Business in foreign ore, though still by no means large, shows improvement, and renewal of activity on a considerable scale appears, at last, to be at hand. Now that stocks are steadily dwindling, and in some cases getting rather low, consumers are coming forward to negotiate. Prices vary a good deal, but may be said to be based on round about 46*s.* c.i.f. Tees for best rubio. Contrary to expectation freights are not falling, and, indeed, 19*s.* Bilbao to the Tees has been paid, which is 2*s.* above the recent parity, and it is stated that contracts over a lengthy period have been made at 17*s.* 6*d.*

Coke.—The large and steady home demand for coke is met by a very ample supply. Recent advances have not checked buying, and sales are reported at 39*s.* at the ovens for average blast-furnace kind, and 41*s.* 6*d.* at the ovens for quality low in phosphorus.

Manufactured Iron and Steel.—So far as finished iron and steel is concerned, home demand for shipbuilding requisites and railway material continues large, but several other descriptions are in only very moderate request. Inquiries from abroad are on quite a good scale, and rather considerable business with the Far East is reported. Export prices are not fixed, but they are rather above the following, which govern the home trade:—Common iron bars, 20*l.* 10*s.*; marked bars, 23*l.* 5*s.*; strip iron, 21*l.* 15*s.*; ship rivets, 27*l.* 5*s.*; steel ship, bridge and tank plates, 17*l.*; steel angles, 16*l.* 10*s.*; steel joists, 16*l.* 10*s.*; steel hoops, 23*l.* 5*s.*; and heavy steel rails, 15*l.*

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—For the first time since schedule prices were introduced into the coal trade under the stress of war conditions, there has been something like competition for coals on the South Wales market. This has been brought about by a new instruction of the Coal Controller under which vessels of all nationalities, irrespective of destinations, are placed on the same footing as far as bunker supplies are concerned. A minimum schedule has been fixed which is the same as that at which cargo coals are supplied to Allies. Previously British, Allied, and vessels named by the Coal Controller, used to obtain their bunker supplies at these fixed rates, and for neutrals there was a minimum which, as far as large coals were concerned, was about 9*s.* above the Allied fixed prices, but for smalls was on a par. In consequence of this change, which, it is expected, foreshadows an alteration all round, prices for bunker coals have varied considerably since the Order came into operation on Monday last. In some instances sellers still differentiated between Allied and neutral vessels by asking for an increase of anything from 5*s.* for both large and small, and for an increase of 10*s.* for neutrals. Generally the increase is from 5*s.* to 7*s.* 6*d.*, but with coals still extremely scarce it is difficult to get an adequate idea of prices. The shortage has been further accentuated by the continuance of the strike of 5,000 miners in the Ebbw Vale collieries, and a stoppage at the Glamorgan collieries lasting three days, and also a cessation of work at the pits of the Naval Collieries. The miners at Ebbw Vale have now decided to return to work pending a settlement of their dispute, but it will be some days before operations are resumed as the horses have been got out of the pits. So far as cargo qualities are concerned there is an extreme shortage and, as tonnage has arrived freely during the past week, the anticipated easier state of affairs has not materialised. Collieries usually are fully stemmed and with tonnage in dock have more than enough business already on hand.

Newport.—Monmouthshire coals of all classes are very scarce and buyers have great difficulty in securing even small parcels. The new Order, under which a minimum price is fixed for bunkers, has caused some competition for coals, and chief interest centres in this section. It is reported that Black Vein large has been sold at 45*s.*, and Eastern Valleys at 42*s.* 6*d.*, which represents an increase of 8*s.* and 6*s.* 6*d.* respectively above the minimum also that smalls have changed hands at 35*s.* for bunkering purposes, an increase of 7*s.* 6*d.* The strike at the Ebbw Vale pits has aggravated the scarcity, and coal, for cargo purposes are extremely short.

Swansea and Oil.—The Right Hon. E. J. Pretyman, M.P., last week laid the foundation stone of the new refinery works of the Anglo-Persian Oil Company at Skewen, near Neath. It is expected that the coming of the Anglo-Persian Company to Swansea will result in great developments in connection with the oil industry. It is intended that special craft shall take the crude oil from large tank steamers in the Swansea Roads. The oil will then be brought into the docks, where the company has secured a large tract of quay space at the King's Dock, and then pumped by pipeline to the refinery works at Skewen, where it will be dealt with, and then returned to the docks for shipment abroad or sent inland by rail. The works, when complete, are estimated to give permanent employment to 4,000 men.

Swansea General Cargo Strike Ended.—The strike of general cargo workers at Swansea, which affected about 1,000 men, and has been in progress for the past two months, was brought to a close at a joint meeting, arranged by the Ministry of Labour, on Monday. It was agreed that work should be resumed forthwith, that the points which were in dispute should be referred to the proper union officials for negotiation and adjustment with the employers, and that negotiations begin forthwith for a general revision of the tariff, such revision to make all practical arrangements for the elimination of "extras." The strike of tinplate annealers at Llanelly and the Cwmbwrla district of Swansea, which brought about the stoppage of 14 works and affected about 4,000 men, has also been settled, and the men have returned to work.

Milling Deal.—Messrs. Spillers & Bakers, Limited, millers, Cardiff, have acquired the corn-importing business of Messrs. J. Hibbert & Sons, which was established by the late Mr. John Hibbert in 1847 at the Cardiff Docks.

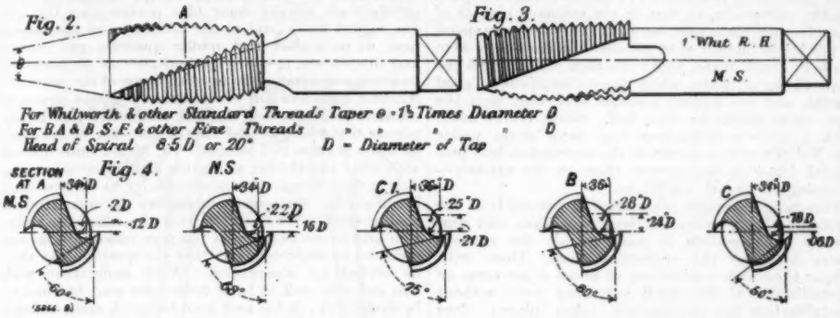
PERSONAL.—Mr. F. C. Raphael, M.I.E.E., was appointed manager of the Cable and Wire Department of the Edison Swan Electric Company, Limited (Ponders End, Middlesex) last month, on his release from the Army. Although Mr. Raphael is best known as having been successively editor of *The Electrician* and *Electrical Engineering*, he had previously been on the staff of cable manufacturing companies in this country and abroad. Mr. Raphael was in charge of cable inspection up to the date of his demobilisation.—Mr. Tudor A. Wilkin, after many years experience in Lime-Soda, Permutit and Sand Filtration, has resigned his late position in order to commence business as Consulting Engineer Specialising in Water Treatment, with offices at 15, New Broad Street, London, E.C. 2. He has also been appointed Technical Representative for the Paterson Engineering Company, Limited, of London, particularly in Wales, where he intends opening additional offices.

THE AMERICAN POTASH INDUSTRY.—According to H. S. Gale, of the United States Geological Survey Press Bulletin of February, 1919, the potash industry of the United States is passing through a critical period. Before the war the country used more than 1,000,000 tons of potash salts of all kinds, and it was thought that the stoppage of the imports would be felt as a keen deprivation, especially by the farmer. Though, however, the home production of potash does not amount to more than a quarter of the former importation, in spite of all efforts, there is little or no market for potash, neither at the high war prices, nor at considerably lower prices. No satisfactory explanation of this peculiar condition has been suggested. Some 100,000 tons of potash salts, produced in Nebraska, are lying in storehouses throughout the south-eastern States, where most potash used to be consumed. The salt is of the same quality as that used in 1917; but there is no demand for it. The term potash, it should be noted, comprises a great variety of potash compounds, fertilisers, chloride, sulphate, cream of tartar, carbonate, caustic, chromates, prussiates, permanganate, nitrate, &c. The 1,092,588 short tons of potash salts imported into the United States in 1913 were equivalent to 270,720 short tons of actual potash. By 1917 the imports had gone down to 25,000 tons, containing about 8,000 tons of actual potash.

HAND AND MACHINE SCREWING TAP.

CONSTRUCTED BY MR. ROBERT SEMPLE, GLASGOW.

FIG. 1.



We illustrate above a new form of tap for producing threads and designed for driving either by hand or by power. The tap is being manufactured by Mr. Robert Semple of 179, West George Street, Glasgow, and is a departure from those usually supplied in that the flutes, of which there are only two, are cut spirally and with a permanent cutting angle. But the firm, whilst maintaining a constant cutting angle on a particular tap, manufactures a series of taps in which the cutting angles are correct for producing threads in the various materials dealt with in manufacturing workshops.

The result is that the tap makes a clean thread by cutting away the material, further, the cuttings—owing to the spiral form of flute—do not crowd in the groove but come away in spiral form in front of the tap, the advantage of this being that the tap may be run in a machine for power tapping at a cutting speed of 50 ft. per minute when working upon ordinary mild steel. The design of the tap is such that only one tap is required to produce the thread, even when working to fine limits, this is a decided economy from the point of view of first cost and in the time taken to complete the work.

We have recently proved in actual use that the tap when worked by hand; takes less power to produce a thread than that required when using a set of two or three taps (that is the taper, second and plug tap) so commonly used on general work.

The tap shown in Figs. 1, 2 and 3 is suitable for tapping through holes and in the sections given in Fig. 4 the various cutting angles adopted by the makers are shown, whilst in the table below are enumerated the classes of material for which these cutting angles are applicable.

Reference.	Cutting Angle.	Material.
M.S.	deg. 60	Mild steel. Wrought iron. Malleable cast-iron. Ubas steel. Bessemer steel.
N.S.	68	Alloy steels. Nickel steel. Vanadium steel. Chrome nickel steel.
C.I.	75	Cast-iron. Cast steel. High speed steel.
B.	80	Brass. Gun-metal. Delta metal. Muntz metal. Phosphor bronze.
C.	50	Copper. Aluminium.

The sizes of the taps have been standardised for a range covering the British Standard Whitworth and fine threads, the British Association threads, and those adopted by the Air Ministry.

The tap may be advantageously used for tapping blind holes, in this case the makers advise that the tap should be made with the spiral flutes cut right-handedly, in order that the cuttings may work up the flutes towards the shank of the tap.

NOTES ON REFRACTORIES.

THE following notes are based on a course of lectures recently delivered at Newcastle by Dr. J. W. Mellor, of Stoke-on-Trent.

A distinct advance in the general refractoriness of firebricks would enable the metallurgical, gas and other industries to introduce improvements now impracticable owing to limitations imposed by the refractories themselves. Siemens was quite right when he said that every improvement in the manufacture of refractory materials has been followed by an improvement in metallurgical processes. In the case of clays the refractoriness is for most furnaces well above requirements, so the life of many can be extended, but it is not likely that the refractoriness of clays could be carried much higher.

The magnitude of the refractories industry is much greater than the majority of people realise. Figures supplied by Sir William Jones, of the Ministry of Munitions, show that the peak-output of the chief firms supplying refractories to munitions works alone during the past three years amounted to 137,465 tons of firebricks, equivalent to nearly 34½ millions of clay firebricks per month, along with 11,159,000 silica bricks and 684,000 magnesite bricks.

Refractory material is mostly made from fireclay, and one of the mine-manager's chief aims should be to send the clay to the brick works free from contamination with material (including inferior clays) from adjoining strata. Such contamination unfortunately happens too frequently, and could often be avoided by the exercise of more care.

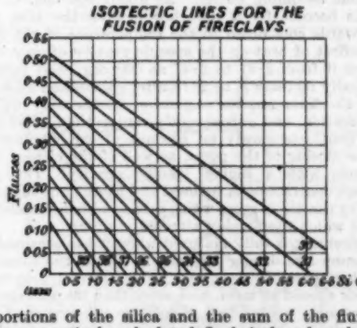
In contemplating the use of a new clay as a refractory, the first step is to ascertain whether the clay is in reality sufficiently refractory to be worth close attention, and, if not, whether it could be made refractory by purification without undue expense.

The test for refractoriness is made so much more rapidly and cheaply that it should come before the analysis, for, in the case of poor material, it might not be worth while to make an analysis. It must be remembered that clays and some other refractories have not a definite melting point like ice and many other substances, but rather a range of temperature within which gradual softening takes place. Hence it is preferable in the case of these materials to use the expression "squatting temperature" or "softening temperature" instead of melting point. The change which makes clay soften starts very slowly at a comparatively low temperature and proceeds more and more rapidly as the temperature rises. Hence a gradually rising temperature with prolonged heating apparently softens a clay at a lower temperature than exposure for a shorter time at a higher temperature. According if a test for the squatting temperature is to be reliable, it must be settled what stage in the gradual softening process shall be regarded as the softening temperature, and also at what rate the furnace temperature shall be allowed to rise. To avoid the multiplication of standards and to facilitate comparison of results the Refractory Materials Committee of the Gas Engineers and the Refractory Materials Section of the Ceramic Society have recommended that the refractory tests be made under certain specified conditions. Refractory tests of fireclays are made with cones as temperature indicators, in preference to using optical or other pyrometers. Dr. Mellor has found electric furnaces to be so satisfactory in carrying out these tests for eight or nine years that he is surprised at the reports from other quarters of unsatisfactory working of such furnaces.

Assuming the refractory test to be satisfactory, an ultimate analysis of the clay is desirable, for it gives valuable information if conducted properly. As a matter of fact, some extraordinary analyses are occasionally met with, and it is necessary that the work should be done by reliable analysts. Objections are sometimes made that analyses are not of much practical value, but this can only mean that the objector does not know how to use analytical results and that he assumes no one else does either.

In the so-called rational analysis the aim is to represent the composition of a clay as so much ideal clay mixed with certain proportions of quartz and felspathic or micaceous material. If this could be accurately done with refractory clays the results would be much more serviceable than the ultimate analysis, being less general and more specific. Unfortunately, some of the general assumptions on which the methods devised for carrying out the rational analysis are based were shown by Dr. Mellor to be wide of the mark. Better results are generally obtained by calculation from the ultimate analysis, the alkalies being first calculated to felspar with the corresponding alumina; the excess of alumina is then calculated, along with the necessary silica, as ideal clay—with two molecules of silica to one of alumina—and any surplus silica is called quartz; ferric oxide would be represented as such.

The composition of a clay can also be represented as a formula by dividing each percentage by the molecular weight of the corresponding substance to give molecular proportions. When thus expressed, with the molecular proportion of alumina taken as unity, and the corresponding values for the molecular



proportions of the silica and the sum of the fluxing oxides respectively calculated, Ludwig found a relation between the composition and the refractoriness. The similarly calculated acid (silica) proportions of the higher Seger cones (when alumina is unity) are marked as abscissæ, and the points corresponding with certain artificial fluxes are also marked along the first ordinate lines; lines drawn obliquely through these points are isotectic lines. The position of a clay the composition of which can be reduced to a formula can be represented by a point on the diagram, and its position relative to the isotectic lines of the cones corresponds with its fusibility. As the formula and the chart involve artificial assumptions, most authorities were prejudiced against them, including Dr. Mellor; the latter, on putting them to the test, unexpectedly found that of nearly 70 British fireclays only about three failed to agree with observation. In the case of ternary mixtures of clay, felspar and quartz the softening temperatures are represented on a triangular diagram. The results are modified by the presence of impurities in appreciable quantities, but are good for high-grade clays.

By excessively fine grinding the refractoriness of a clay can be lowered two or even more cones, but the fact that most of the clays fit in with the scheme indicates that the deviations of natural clays from the average is too small to affect the result, so far as high-grade clays are concerned; the arguments do not apply in the case of low-grade clays.

China clay and quartz are both highly refractory under ordinary furnace conditions, and when pure squat at about cone 35. China clay alone cannot be made more refractory, but it can be made more refractory by mixing with alumina or certain other expensive materials, as in a mixture of about equal parts of china clay and alumina used in making furnace

tubes, which stand at cone 38. China clay and quartz mutually impair each other's refractoriness, an intimate mixture of 20 per cent. china clay and 80 quartz having the lowest fusing point at about cone 26.

Few fireclays are washed, and unwashed clays have a grain size depending largely on the non-argillaceous constituents. A well-weathered clay seems to have films of water separating its particles. Hard clays are ordinarily ground, and the lumps or knaps, the size of which depends on the grinding, are clots or aggregates of the finer grains of clay. In bricks their behaviour is like that of badly-fired grog. When wet clay is left standing for a few weeks the knaps are gradually broken down by the water. Clays thus prepared are usually easily moulded and worked, but they do not dry satisfactorily. Hence, to facilitate the drying of plastic clays a non-plastic opening material is added, generally grog. The grain size of the grog should be suited to the purpose for which the refractory is intended.

Some makers riddle out the dust from grog before mixing it with the clay, but in some cases it is apparently overlooked that the edge runner pan on which the mixing is effected exerts a grinding action, producing fine-grained silica again, and so losing control of the grain size. In all cases uniform mixing is necessary for the best results.

The results of heating clay with a gradually rising temperature are that first hygroscopic moisture and water from dehydration of colloidal silicic acid are lost; then at about 500 deg. C. the clay is decomposed into free silica, free alumina and water; at about 800 deg. the alumina begins to polymerize, more complex molecules being formed; above 1,000 deg. the alumina and silica combine to form sillimanite ($Al_2O_3 . SiO_2$); at 1,500 deg. the clay sinters to a stone-like mass; at 1,650 deg. the clay softens and loses its shape; and at 1,700 deg. C. it forms a brown or grey viscid liquid. Some assume that the compound $Al_2O_3 . 2SiO_2$ is formed when the water of constitution is expelled, but the only evidence is the fact that the analytical ratio is the same before and after dehydration of the clay, and this would be the case whether the silica and alumina were combined or not. At about 500 deg. bricks in the kiln during the burning absorb heat without becoming hotter. At about 900 deg. C. the bricks become for a time hotter than the kiln, and afterwards cool down to the temperature of the kiln. The effect of heat on the specific gravity of clay is to reduce it from 2·61 to 2·47 at 600 deg., and then to gradually increase it to 2·73 after calcination at 1,200 deg. C. This implies expansion of the clay during dehydration, and subsequently contraction. The fireclay contracts slowly on account of the vitrification or the closing of the pores, as well of the change to a mixture with a higher specific gravity. The percentage contraction is reduced and made more manageable by the use of grog, which acts as a kind of skeleton, about which the fireclay vitrifies or sinters.

A firebrick is fully matured when it has attained its minimum size during the firing. To get the soundest and best possible brick of a given texture, grog fully shrunk should be used, and more than 99 per cent. of the possible contraction should be taken out of the bricks during burning. A practical test for ascertaining if a brick has been properly fired is to heat one-half of it in a furnace in which similar bricks are used and then compare it with the other half. In the standard test a brick is heated for a specified time at a specified temperature, and condemned in case the residual or after-contraction exceeds the specified minimum. The Gas Engineers' specification has had the effect of lowering the average after-contraction of commercial bricks from about 2 to about ¼ per cent.

The effect of heating alumina with gradually-rising temperature is to increase the specific gravity from about 2·8 at 600 deg. to about 3·9 at 1,200 deg. C., the contraction amounting to nearly 30 per cent. The change is an exothermal reaction, heat being evolved. Bauxite is mainly alumina, with varying proportions of iron oxide, titanic oxide, &c. The great contraction of bauxite or alumina bricks causes practical difficulties in the manufacture, the products being liable to crack and become distorted, and the completion of the reaction being uncertain. The serious trouble often resulting from the use of inadequately shrunk bricks has caused bauxite or alumina bricks to be condemned by both maker and user, so they have not had a fair chance to show their capabilities. When thoroughly shrunk by fusion the bauxite or alumina makes very satisfactory refractory bricks, but the fusion as usually carried out in electric furnaces is too expensive for commercial purposes. In France it is claimed that bauxite can be melted economically by the Lecesne process, and the fused bauxite so obtained is known commercially as "corindite."

The high temperature calcination of magnesia causes a change of specific gravity from about 3·2 to about 3·6, corresponding with a contraction of more than 11 per cent. The change is hastened by the presence of ferric oxide. Magnesite bricks are made without the addition of any foreign binding agent.

Dr. Mellor prefers a highly plastic and tenacious clay as bond for silica bricks rather than lime. A small proportion of plastic clay forms crystals of sillimanite, but even then the bond is stronger with the clay than with the lime bond, though the lime bond is probably most generally used.

The change from quartz to low specific gravity forms of silica on heating is very slow. Heating for four hours just below the fusing point of quartz results in only a small conversion. There is a difference in the rate of conversion of different silicious rocks from different localities. The conversion is much more rapid with flint than with quartz. There is evidence that presence of iron oxide in a certain form can speed up the conversion, so that in the ordinary process of manufacture there may be a 60 per cent. conversion in the bricks instead of 30 per cent. Some bricks were made in South Wales with silica rock containing 5 per cent. of ferric oxide, which gave exceptionally good results, and one furnace manager said they were the best silica bricks he ever had. Silica bricks made with a little carbonaceous clay have come under Dr. Mellor's notice, in which the conversion had proceeded faster in the interior than on the exterior—reversing the usual conditions.

Generally expansion takes place in passing from the crystalline to the vitreous glassy condition, and conversely a contraction in passing from the vitreous glassy state to the crystalline form. Thus, with felspar there is a contraction of about 6 per cent. on crystallising. If the fused substance cools without crystallisation no contraction takes place; thus vitreous quartz vessels contract in crystallising and become shattered when crystallisation takes place. There seems to be a temperature which specially favours crystallisation. Disintegration of porcelain pyrometer tubes and also of vitreous quartz have been observed under such conditions.

Fine grinding of silica facilitates conversion into a low specific gravity form. The conversion seems to proceed from the surface to the interior both of the brick and of the individual grains, and increased surface (with increase in the number of grains) accounts for the increased conversion. But the finer the grain the greater the proportion of bond, which is the weakest part of a silica brick in use, so the advantage due to rapid conversion is opposed by the disadvantage of greater bonded surface. Firebricks in general must be considered in connection with the work they have to do in particular parts of furnaces, not with reference to a furnace as a whole.

It generally happens that the nearer the composition of a refractory is to that of the slags it has to resist, the better it acts; acid bricks suit acid slags and basic bricks suit basic slags.

For resisting the corrosive and cutting action of slags the texture of a refractory should be as fine grained as practicable and free from surface flaws.

A peculiar penetration takes place with some dusts. With dusts of oxides of iron, copper and zinc in a reducing atmosphere penetration may take place to the extent of an inch in a couple of hours. There is some evidence of volatilisation of these metals at such unexpectedly low temperatures as 600 deg. for copper and 1,100 deg. C. for iron. Dr. Mellor therefore believes these metals penetrate the refractory as vapours. A fine-grained texture of the refractory is best for resisting both vapour and dust. Penetration by zinc vapour has long been known in industrial operations, but the possibility of copper or iron vapour being produced may perhaps suggest explanations of some metallurgical processes not well understood.

Ferruginous dusts in reducing atmospheres produce rapid slagging, in contact with silica or fireclay refractories. Thus a steady dripping of slag was caused by a ferruginous coal ash (flue dust) coming in contact with the bottoms of retorts heated by producer gas.

In the case of salty coals some salt vapour passes on and rapidly attacks silica and fireclay. The slag produced by its action on clay is very fusible, and the same reaction is utilised in the ordinary process of salt-glazing drain pipes, &c. So far as chemical composition is concerned it would seem that bricks with a molecular ratio alumina to silica of less than 1:3·5 are best for resisting such action; one good resister contained 63 per cent. of silica and 30 per cent. alumina.

Among minor points worthy of attention may be mentioned the use of wet grog rather than dry grog to mix with wet clay. There is an appreciable difference in the behaviour of the products obtained, and generally in favour of the grog soaked in water. When a piece of wet clay is dabbed on a dry slab of plaster, a film of dried clay is soon formed in contact with the plaster and the piece of clay drops off; but if the plaster slab be wet the film of dried clay is not formed and the clay sticks fast to the plaster. The behaviour of wet and dry grog seems to be similar. This afterwards influences tensile strength, crushing strength and contraction of the brick, all being best with soaked grog.

Fireclays up to about 1,000 deg. C. become tougher as the temperature rises, but at higher temperatures they begin to show signs of the viscosity which characterises liquids, and fluidity (the inverse of viscosity) increases as the temperature rises. When a firebrick is heated under load, the refractoriness of the clay apparently decreases with increase of the load. With pure china clays the apparent refractoriness decreases about one cone for every 5½ lb. increase of load. Generally the more silicious the clay the less the difference between its refractoriness with and without load.

Materials for withstanding abrupt changes of temperature are usually made of a porous open texture, due regard being paid to the preserving of the toughness, as in muffles and muffle quarries, gas retorts and zinc retorts, in which the limitation of permeability to gases necessitates the keeping down of the porosity. Another consideration which makes a porous structure undesirable is the low thermal conductivity of highly porous materials, at any rate in the case of low-temperature muffles and retorts. Dr. Mellor finds himself somewhat unorthodox as regards highly porous retorts, &c., at high furnace temperatures, for he believes that in this case the porous structure favours thermal conductivity. He considers that the effects of radiation and convection across the pore spaces are far too great to be neglected, but that the question can only be settled by observation. Work undertaken with this aim was well in hand before the war, but had to be suspended; it has now been resumed, and a definite result is hoped for soon. The point is exceedingly important in heat engineering.

The consumer has to consider carefully the prevailing conditions in particular parts of furnaces, so as to select the most suitable refractories.

In a blast furnace the bricks near the top do not experience high temperatures, but they have to resist some abrasion, impact and change of temperature. These bricks are liable to spalling and disintegration, attributed to the deposition of carbon liberated in reactions between the furnace gases and the iron oxide in the bricks, especially when the iron oxide is not uniformly distributed. The bricks should be close and compact, and as such bricks are usually tough they are less permeable to gases. The temperature conditions increase in severity in descending the furnace. The upper parts of the lining normally have some protection from a surface film of carbon, but friction of the descending charge and the impact of fine particles of solid carried forward by the blast may produce erosion, especially if concentrated locally. The bricks in the mid zone also suffer from the slagging effects of salt particles and other basic fluxes from coke, &c., but there are no abrupt temperature changes; a close-grained compact brick is the most suitable here. In the hearth and bosh the prevailing conditions require a very special brick, which has to resist high temperature, the scouring action of highly basic slag, and a heavy mechanical load, and should have small volume changes, since the bricks must be tight without leakage; there is no great amount of wear and tear by abrasion. The stove bricks should have high thermal capacity (so as to absorb and give up the maximum amounts of heat), and should be capable of resisting the sand-blasting action of flue dust.

The specific heat of firebricks increases rapidly with rise of temperature, so that up to 1,300 deg. C. the specific heat at temperature t deg. is $0·193 + 0·00006\,t$.

ENGINEERING STANDARDS IN AUSTRALIA.—The question of engineering standards is being taken up keenly by engineers of the Commonwealth, says *The Board of Trade Journal*. At a recent meeting of representatives of Government departments, the Chamber of Commerce, University of Tasmania, and the Electrolytic Zinc Company Prop., Limited, held at Hobart under the auspices of the Advisory Council of Science and Industry, to discuss the establishment of an Australian Engineering Standardisation Committee, the following resolutions were adopted: (1) That the meeting heartily endorses the suggestion for the establishment of an Engineering Standardisation Committee of Australia, and urges prompt action in connection therewith. It further recommends that the committee should be, in the first instance, formed by appointments on the recommendation of the engineering societies of Australia, such appointments to include manufacturers' representatives, and also by appointments representing Government departments and public utilities. (2) That the meeting affirms the principle that British standards should be adopted as far as possible. (3) That the representatives present at this meeting undertake to urge upon the bodies they represent to support the principle of standardisation, and to prepare the ground for the Australian Engineering Standardisation Committee by adopting the British standards forthwith wherever possible.

DEVELOPMENTS IN ELECTRIC IRON AND STEEL FURNACES.*

By JAMES BIBBY.

THE author proposes to confine his remarks in this paper to some of the recent developments in the manufacture of iron and steel by means of electric furnaces, as he imagines this will be more acceptable than to treat the whole subject generally.

Let us first consider the application of electricity to the reduction of iron ores, namely, to the manufacture of pig-iron. Iron occurs in nature in the form of oxides, which can be reduced in contact with carbon at certain temperatures. In the electric furnace the function of electricity is to bring the ores and reducing agents to the temperature at which reduction takes place, and then melt the resulting metal together with the fluxes. Although there are technical advantages in electric heating over direct fuel heating, the commercial success of the electrical reduction of iron ore depends on the price of electricity as compared with that of fuel. The profitable application of the electrical process is therefore limited to those districts where cheap electric power can be obtained.

The manufacture of pig-iron in a blast furnace requires, on an average, 1 ton of coke per ton of pig-iron produced. Given the same ore, an electric furnace would require 0·3 ton of coke per ton of pig-iron produced thus effecting a saving of 0·7 ton of coke per ton of iron. Against this saving in coke must be set the consumption of electrical energy, which averages 0·3 h.p.-year per ton of iron. This means that, other conditions being equal, the costs of the two systems balance when 1 h.p.-year can be obtained for the price of 2·3 tons of coke.

Electric pig-iron contains less impurities than pig-iron from the blast furnace, owing chiefly to the smaller quantity of coke used and to the higher temperature obtainable. The higher temperature makes it possible to work with a more basic slag, which favours the elimination of sulphur. There are now over 20 electric furnaces working on the manufacture of pig-iron, and, at the moment, about 12 more are being installed, which is a good indication of the commercial hold the system is taking.

* Paper read at a joint meeting of the Institution of Electrical Engineers and the Iron and Steel Institute, on Thursday, May 8, 1919.

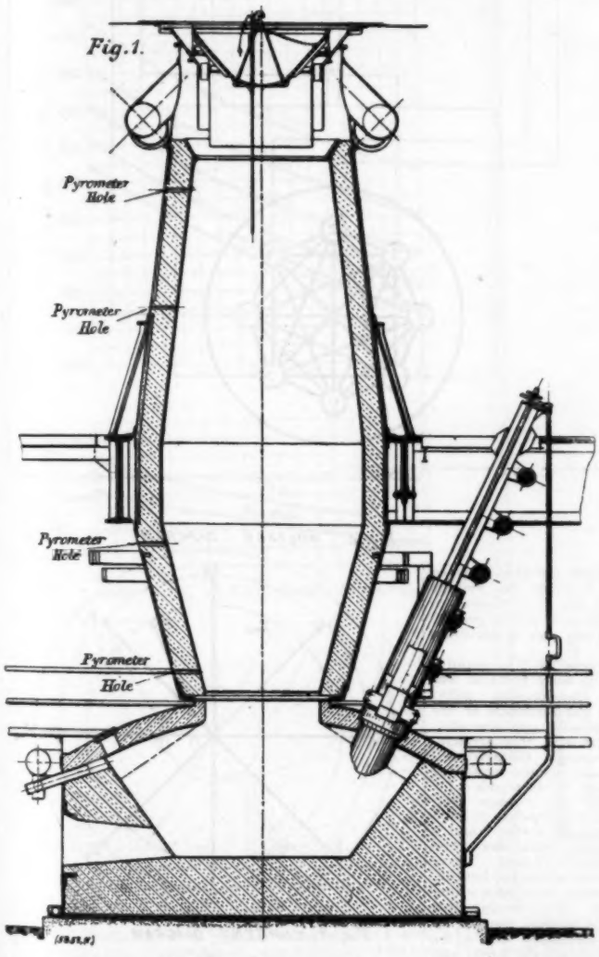
The general appearance of the electric reduction furnace Fig. 1 follows that of the blast furnace fairly closely. The stock charging and hoisting gear are the same. The shaft is somewhat similar, except that it is only about 30 ft. high instead of 80 ft. At the point corresponding to the tuyere belt in the blast furnace the shaft proper of the electric furnace ends, and, in place of the narrow blast-furnace hearth, there is provided in the electric furnace a wide shallow hearth or crucible, the shape of which is characteristic. This crucible forms the melting and refining chamber, and it is with the occurrences in this chamber that the electrical engineer is chiefly concerned.

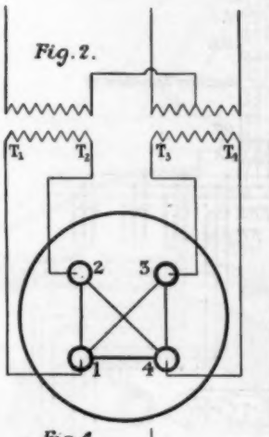
In the blast furnace the necessary heat is generated in the tuyere zone by the combustion of the coke indirectly to CO. The hot combustion products ascend the shaft and reduce the ore in the zone in which a sufficiently high temperature obtains. The reduced iron, in the form of sponge, descends the shaft and is melted in the fusion zone round about the tuyeres, whence it trickles down to the hearth. In the electric furnace the necessary heat is generated by the resistance to the passage of current between the electrodes, which project through the roof of the crucible and are embedded in the charge.

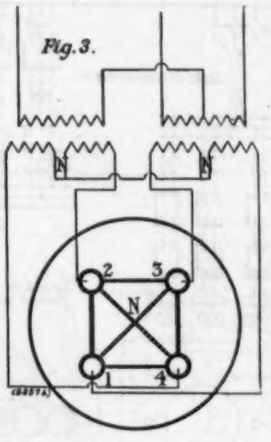
At this stage we may consider the chemical action taking place in the electric furnace. The iron ore, coke, and flux are charged at the top of the furnace, and these, in descending, are heated by the ascending gases generated at the base of the shaft and top of the crucible by the final reduction which takes place in this region. When the temperature of the ore, Fe_3O_4, has reached about 250 deg. C., it is reduced to a lower oxide, FeO, by part of the ascending CO, forming CO_2. The full reduction process can be set out as in Fig. A.

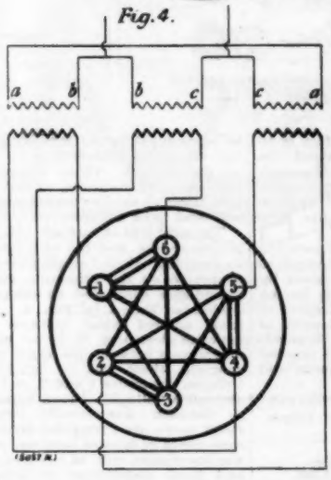
It will be seen that with every molecule of magnesite ore there should be three molecules of carbon, and that the final yield is three molecules of iron which descend, two of CO and one of CO_2 which ascend; so, theoretically, there are 12 parts by weight of carbon charged to 56 of iron produced, that is 22 per cent., and it is satisfactory to find that, in the furnaces built recently, no more than this quantity of carbon is consumed per unit of iron produced. The first reduction to ferrous oxide by CO is at the temperature of 250 deg. C. mentioned above, but the reduction of the ferrous oxide by solid carbon does not commence until a temperature above 800 deg. C. is reached, so that reduction is not completed until part of the oxide is in the crucible.

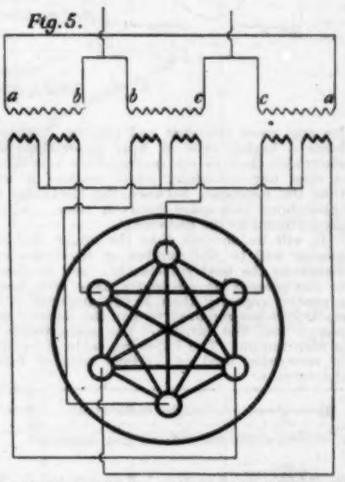
It will be noticed from the equations that in the electric process the whole of the gas is produced from the oxygen in the ores and the carbon in the fuel, neglecting flux action, whereas in the blast furnace a large quantity of external air must be introduced to provide the balance of oxygen necessary for the combustion of the fuel for heating. In the electric furnace the gas generated is only one-eighth of that generated in a blast furnace for the same duty, but its calorific value is nearly three times as high, because it contains no nitrogen.











$$\downarrow \quad \downarrow \qquad\qquad \downarrow \quad \downarrow$$
$$Fe_3O_4 + 3C + 3CO \rightarrow 3FeO + 3C + CO_2 + 2CO \quad (1)$$
$$\uparrow \qquad \downarrow \quad \downarrow$$
$$3Fe + 3CO \leftarrow 3FeO + 3C \quad . \quad . \quad . \quad (2)$$
$$\downarrow$$

FIG. A.

Besides the melting and final reduction operations in the crucible, we have to melt the flux so as to form a slag with the gangue of the ore and the ash of the coke, and at the same time eliminate as much as possible the sulphur introduced by the ore and the coke. The sulphur is eliminated through the agency of the lime, forming calcium sulphide, which is retained in the slag. The slag should be highly basic in order that it may absorb the sulphur, which would otherwise remain in the iron as sulphide of iron. This necessitates a high temperature, owing to the high melting-point of lime; but it would be futile to have a high temperature at one part of the metal-slag contact area and a low temperature at another, as in that case the sulphur would pass back from the slag into the metal, at the cold places, and neutralise the good work at the hot places. The heating system must therefore be arranged so as to develop a uniformly high temperature throughout the central and lower portions of the crucible. We can now consider the means which are taken to accomplish this thermal state.

As before mentioned, the heat is developed by the resistance of the loose charge to the passage of current between embedded electrodes. It is difficult to ascertain the voltage gradient throughout the charge, in the varying form in which it appears in the crucible, where it consists of ferrous oxide, melting iron, gangue, fluxes and small portions of coke. It appears, so far, impossible to obtain as high a voltage drop across the crucible this carbon descends, without change, till the temperature is sufficient for reaction which equation (2) shows

as we should like; and the drop does not increase quite in proportion to the distance, indicating, as would be expected, that there is a considerable drop between the electrodes and the material, which drop is constant for any given electrode and current. The effect is to have a higher rate of heat generation around the electrodes than in the intermediate spaces. However, it does not materially affect matters if we consider that the resistance between the electrodes is uniform throughout the space between them, *i.e.*, that it is proportional to the distance.

It will be obvious that the larger the furnace the greater will be the number of electrodes required to distribute the heat sufficiently; and further, since up to the present no electrodes have been made having a greater capacity than 20,000 amperes, a number of electrodes are required to get the desired quantity of energy into the furnace. The main factor, however, is distribution. The following table gives the number of electrodes used on various sizes of furnaces and the outputs:

Horse-Power.	Number of Electrodes.	Yearly Output.
		tons.
2,500	4	7,000
4,000	6	11,500
6,000	8	18,000
10,000	12	31,000

Commercially the smallest furnace is the 2,500 h.p., with an output of 7,000 tons of pig-iron per year. In this furnace we have four electrodes coupled to the secondary terminals of a Scott group; and the first scheme was to connect them as shown in Fig. 2, where the lower part of the diagram represents a horizontal section through the crucible at the ends of the electrodes Nos. 1, 2, 3 and 4. The voltages across the electrodes 1–2 and 3–4 will be equal, but the voltages between the other pairs of electrodes need not be the same; for instance, there is no need for any voltage drop between electrodes 2 and 3, in which case there would be no current passing between these electrodes and no heat generated in the space between them. Similarly, the voltages between electrodes 1 and 4 may be 1·4 times the phase voltage, and in this case there would be an excess of current, and consequently excessive heating, between electrodes 1 and 4. The lines between the electrode circles represent roughly what may be considered to be the lines of heat generation in the crucible. The effect was to produce excessive heating at certain places, for example, between 1 and 4 electrodes, and deficient heating at other places, say between electrodes 2 and 3, resulting in irregular working and, what was of serious importance, undue destruction of the lining, especially of the roof near the overheated portions. This difficulty was overcome in a very simple manner, as shown in Fig. 3, where the neutrals on the secondary side of the Scott group were connected so as to obtain the effect of four equal independent phases between each electrode and an imaginary neutral point. The potential between the electrodes and the neutral can be represented by the semi-diagonals, and that between the electrodes, externally, is 1·4 times the voltage to the neutral. These voltages are proportional to the respective distances, so that the rate of heat generation along all the line connecting every pair of electrodes will tend to be uniform.

The next size of furnace, viz., the 4,000 h.p., requires six electrodes, and the idea on the early furnaces was to employ three single-phase transformers, delta-connected on the primaries, and the terminals of the secondaries connected to diametrically opposite electrodes, as shown in Fig. 4. Although this arrangement secured equal voltages between diametrically opposite electrodes, it by no means ensures regularity of voltages between the other pairs of electrodes; for example, there was no cause for any voltage drop between electrodes 1 and 2, and it was possible to have as high a voltage between adjacent electrodes 1 and 6 as between diametrically opposite electrodes. The result was a very irregular distribution of heat. There were zones of intense heat and zones where the heating was insufficient and, as a consequence, deficient working and local destruction of linings. The trouble was remedied, as in the four-electrode system, simply by connecting the neutrals on the secondary side so as to secure the three phases being relatively fixed, and obtain the equivalent of six equal phases at 60 deg. The heating effect is approximately as shown by the lines in Fig. 5, and the improvement is obvious on comparing the two diagrams.

The next size of furnace, the 6,000 h.p., has eight electrodes and, for many reasons, it appears that this is destined to be the most popular size. For this furnace we require to transform three-phase current into eight equal phases consecutively at 45 deg. There may be other ways of obtaining this transformation statically, but the plan which has been adopted is that which will now be explained. Five transformers, with relative ratios as marked, are connected on the primary side as indicated in Fig. 7, and the secondary terminals are connected to the electrodes in the order shown. The neutrals are connected for the same reason as on the smaller furnaces. When correctly proportioned, we obtain eight equal voltages induced between every electrode and the neutral. From the voltage vector diagram (Fig. 8) it will be seen that the voltage between No. 1 electrode and the neutral is equal to the vector sum of the voltages induced in N P and N M and represented in the diagram by O P and O M, giving the resultant E_1. Similarly, the voltages between the other electrodes and the neutrals are represented respectively by the equal vectors, E_2, E_3, E_4, E_5, E_6, E_7 and E_8, at 45 degr. progressively, which satisfies one condition of the system.

From the electric supply standpoint it is important that when equal currents are taken through all the electrodes, three equal currents should be taken from the primary mains. Fig. 9 is the current vector diagram, from which the current relationships can be followed, assuming that equal currents are taken through each electrode. The lines 1_{is}, 5_{ic}, 3_{is} and 4_{is} represent the currents induced in the primary C by the respective transformers. The vector sum of these currents is twice I_c. Similarly, the currents in the other primaries

Fig. 6. DIAGRAM OF CONNECTIONS FOR 6-4000 HP ELECTRIC REDUCTION FURNACES.

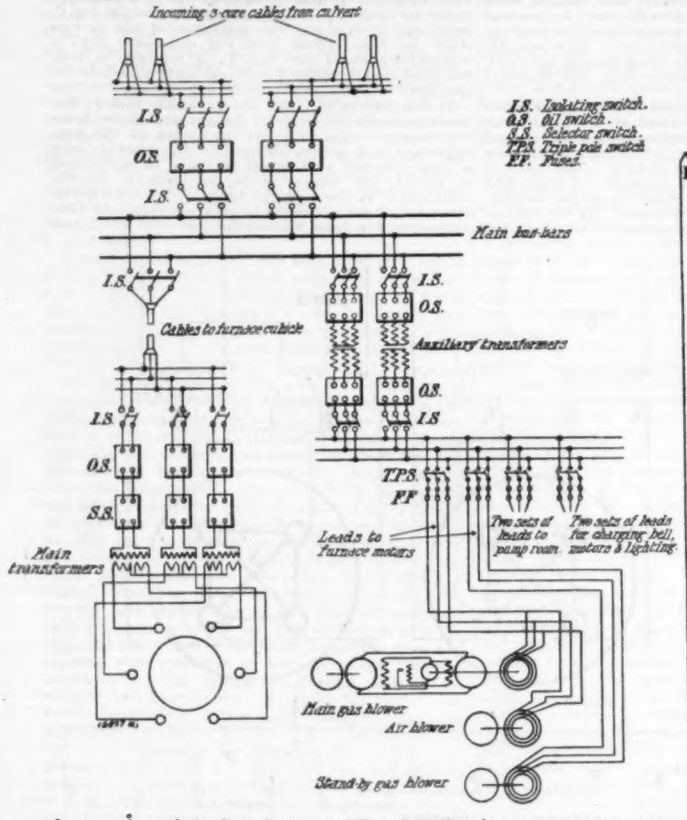


Fig. 7. ELECTRO METALS REDUCTION FURNACE SYSTEM

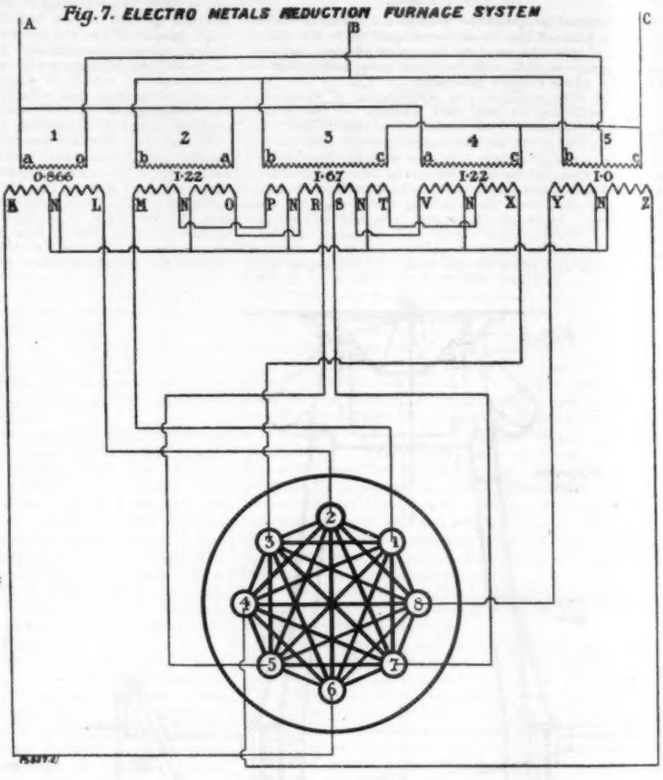


Fig. 8. VOLTAGE DIAGRAM

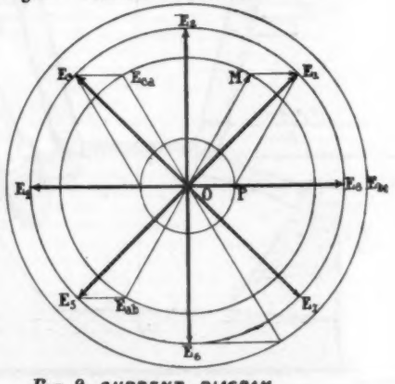
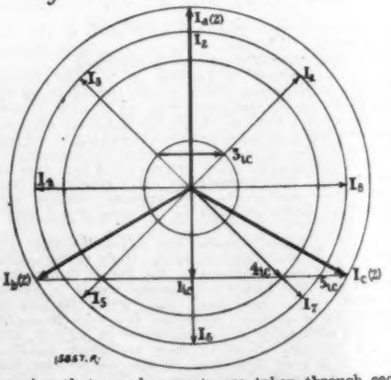


Fig. 9. CURRENT DIAGRAM



are represented by twice Ia and Ib. This system satisfies the electrical condition for balance between the primary and secondary sides, and at the same time secures an exceptionally good heating distribution.

It will be observed that, if the electrodes are set out as shown in the diagram, the effective voltage between any pair of electrodes is proportional to the distance between the centres, and, consequently, if the resistance were constant, the amount of heat development could be represented by the lines drawn between the pairs of electrodes. As previously explained, this is not precisely what happens, since there is a constant voltage drop between the surface of the electrodes and the adjacent material.

The securing of a uniformly distributed high temperature gives the electric furnace an advantage over the blast furnace in this respect. In the blast furnace the temperature of the hearth is fixed by the possible temperature of the combustion at the tuyere zone, say, 1,800 deg. C., and this determines the melting-point of the flux, that is, the possible proportion of lime. Now, in the electric furnaces we have no such limiting

Fig. 10. FUEL & ENERGY CONSUMPTION FOR ELECTRICAL REDUCTION OF MAGNETITE (Fe_3O_4)

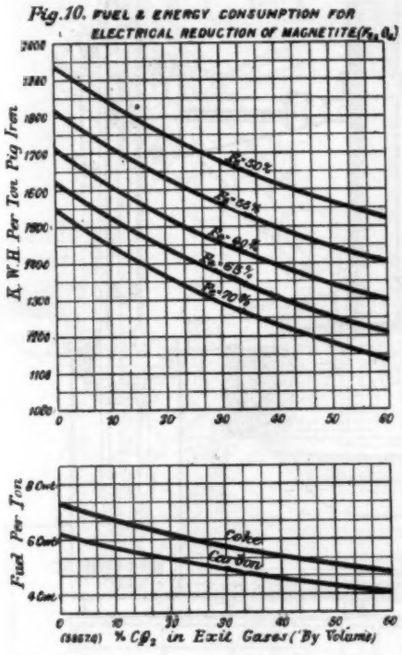
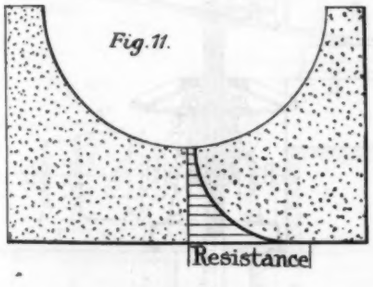


Fig. 11.



temperature, and it is possible to have a flux with a melting-point of 2,000 deg. C., which permits of its being more highly basic and therefore more effective as a refining agent.

It might appear that the current passes horizontally between the electrodes, but this is not exactly what takes place in the crucible, as a portion of current is deflected through the molten metal on the hearth. Consequently, as the bath of metal rises, the resistance decreases, until a point is reached when it is impossible to get sufficient energy into the furnace, and the bath must then be tapped. This limit corresponds to that set by the height of the tuyeres in a blast furnace; but the growth of the bath is much slower, owing to its greatly superior width. An electric furnace is tapped every 4 hours or 5 hours to suit the shifts.

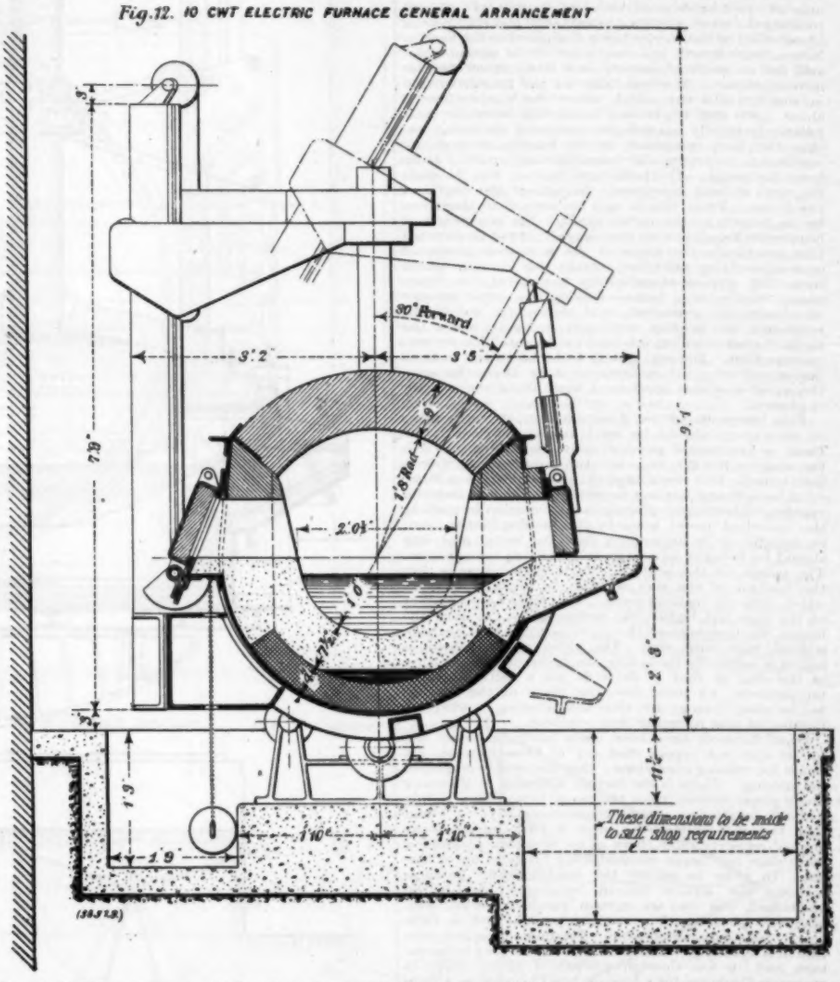
The high temperature in the crucible would be destructive to the roof, even with regular heating, and to avoid this a portion of the outgoing gases is extracted from the main, taken through coolers and dust extractors, and blown against the roof through the free space between the charge and the roof. The gases are cooled to a temperature of about 70 deg. C., and it is found that if about two-thirds of the gases are circulated the roof is effectively preserved. At the same time, this circulation assists in carrying the heat from the crucible into the shaft so as to effect the first reduction of the ore at a higher level. It will be observed that under this arrangement all the gas generated passes, on the average, three times through the shaft; but there is a distinct thermal loss by the amount of cooling necessary.

To ensure the proper working of the furnace under the inevitably varying conditions of the charge, it is necessary to have full control of the circulation gases and the electric energy delivered to the crucible. Regarding the energy supplied, it is not possible to have regulation of current, but the transformers are arranged with tappings on the primary side so as to give about eight steps of voltages on the secondary, varying from 25 to 50 between the electrodes and the neutral. The circulating gases are regulated by a direct-current motor-driven fan with wide speed regulation.

The general electrical scheme of a 4,000 h.p. six-electrode furnace is shown in Fig. 6, which is fairly self-explanatory. It will be observed that a motor-generator set is fitted for operating the fans. The single-phase transformers are of 1,200 k.v.a. each, shell type, water-cooled, with connected neutrals.

One of the most important points for consideration on the electrical side is the arrangement of the low-tension leads; each lead has to take a current of the

Fig. 12. 10 CWT ELECTRIC FURNACE GENERAL ARRANGEMENT



to the equation previously given where the final gas consists of $2CO + CO_2$, which gives 56 of CO to 44 of CO_2 by weight, that is, 44 per cent. of CO_2, which is equal to about 33 per cent. of CO_2 by volume. Fig. 10 shows the consumption of energy for various percentages of iron in the ore, and various percentages of CO_2 by volume, in the waste gases. In a good case of 33 per cent. CO_2 and 70 per cent. iron content, the consumption was only 1,320 kw.-hours per ton. The average obtainable, however, is 22 per cent. of CO_2, and with, say, 60 per cent. iron content the consumption is about 1,500 kw.-hours per ton. The consumption of fuel is given in the lower table, where the bottom line indicates the consumption of pure carbon, and the top line that of coke per ton of pig-iron. It will be seen that for 22 per cent. CO_2 the consumption of coke is only about 6 cwt. per ton of pig-iron, excluding that required for carbonising the iron, and this is a common figure in practice.

The working of the electric reduction furnace requires quite as much skill as the working of the blast furnace, but it is under better control and has

order of 20,000 amperes, and therefore the greatest care must be taken to avoid induction. As an example of the losses which may occur in the low-tension leads, it was found, in a test on an early furnace, that the output from the transformer was about 4,000 kw., but the input to the electrodes was 3,400 kw., showing a loss of 600 kw. The losses are distributed as follows:

	Kw.
In the contact clamps at the electrodes	120
In the resistance of the leads	165
By induction	315
Total losses	600

The heavy induction losses were chiefly caused through the leads having to pass near the structural ironwork of the furnace. By rearranging the leads and interleaving the bars the induction losses can be brought down to about 50 kw. On well-designed plants a power factor of 90 per cent. is obtained, and a load factor of 80 per cent.

The power consumption per ton of pig-iron produced depends chiefly on the percentage of iron in the ore, on the percentage of CO_2 in the waste gas, and on its temperature. The ideal process would be to burn the whole of the carbon to CO_2, but the reducing value of the gas rapidly decreases as the percentage of CO_2 increases, until a point is reached when reduction ceases. In the electric furnace it has been found possible, under the best conditions, to approximate

greater possibilities for the production of various grades of iron.

Electric Steel Refining Furnaces.—The application of electricity to steel-refining has become much more general than to the manufacture of pig-iron, inasmuch as in the former the price of electrical energy, although an important factor, is not the predominating one in determining the commercial value of a proposition.

In steel-making, electricity has advantages which place it well ahead of other heating systems. The chief of these advantages is that the heat can be supplied in easily regulatable quantities and intensities, free from contaminating gases. Moreover, the process can be carried on in a reducing atmosphere, which is of capital importance. Of the many methods of applying electricity that have been tried, the only one which has survived is the direct-arc type, in which the metal is heated by arcs struck between electrodes and the bath of metal itself. An incidental advantage of this system is that the slag is brought to a higher temperature than the metal, which is very desirable on account of its higher melting-point, and, further, it is the most direct method of getting the heat into the metal.

In this part of the paper the author will deal with only some of the features connected with this particular system. Two types of furnaces have been developed on these lines, one in which all the electrodes are above the bath, and the other in which the electrodes are both above and below the metal. The first point to observe

is that the resistance between any two upper electrodes is equal to the resistance of two arcs (the resistance of the metal being negligible), whereas the resistance between an upper electrode and a lower electrode is equal to one arc plus the resistance of the hearth. Now, in order that a number of phases may be in balance, it is necessary that the resistances in the phases be equal, *e.g.*, if we have a three-phase furnace system we must have three equal resistances. In the Héroult three-phase system there are three upper electrodes connected to the outside terminals of three single-phase transformers. In this system the resistance between each pair of phases is equal to that of two arcs, so that the arrangement gives a balanced system when correctly regulated.

If we have a three-phase system with two upper electrodes and one lower electrode, the resistance between the two upper electrodes will be equal to that of two arcs, and the resistance between either upper electrode and the lower electrode will be equal to that of one arc, plus the resistance of the hearth; so that, in order that the system may be balanced, the resistance of the hearth must be equal to that of one arc to bring the total resistance to two arcs, and this results in one-third of the energy being dissipated in the hearth. Now a basic hearth is a conductor of the second class, and the resistance decreases as a function of the rise in temperature. The resistance on the hearth surface in contact with the metal, where the temperature is about 1,800 deg. C., is very small, but increases comparatively rapidly towards the bottom of the lining; so that the heat generated in the hearth, through its resistance, is principally towards the outside, away from the metal. The horizontal lines in Fig. 11 show the rate of heat generation throughout the depth of the lining. From this it will be seen that there can be no benefit to the metal through the generation of heat in the lining, but, on the contrary, it can be assumed that practically the whole of the heat thus generated is dissipated by radiation outside the furnace, rather than that any is absorbed by the metal. A three-phase furnace, or a furnace having any other number of phases, so connected, and depending on hearth resistance for balance, although it might seem the simplest plan to adopt, is bound to be wasteful in current consumption. For any system to be balanced, without the introduction of resistances other than the arcs, the number of arcs must be a multiple of the number of phases.

This brings us to the determination of the number of arcs which should be used in an electric furnace. From a mechanical point of view the fewer the arcs the simpler the system; but the minimum number is determined by metallurgical considerations. There must be sufficient heating zones to melt the raw material rapidly, without necessitating undue exertion in pushing the unmelted metal towards the melting zones, and, in refining, it is imperative that the metal and slag should be brought to a high and uniform temperature. The reason for this uniformly high temperature is that the basicity of the slag depends on its lime content, which fixes its melting-point. The higher the content of the lime the higher the melting-point, so that the higher the temperature the more possible it is to have a fluid, high basic slag. The extent of the chemical action is indirectly limited by the minimum temperature of the slag, so that in order to get a uniformly high temperature, we must have no place in the furnace too far away from an arc, thus necessitating an adequate number of arcs to secure this condition.

Small furnaces have been made having a single arc, but it does not appear that any of these furnaces are in use for refining operations; they are simply employed for melting. There is the further difficulty of obtaining single-phase current from the usual three-phase supply without employing rotary transformers. It is found that two arcs sufficiently cover a bath up to about 6 tons' capacity, and there is no necessity to employ more than two upper electrodes for furnaces up to this size. In order to satisfy the conditions for balance, without the serious hearth resistance loss before mentioned, the two-arc system employed must only have two phases with a common neutral and as little hearth resistance as possible. Fortunately, a dolomite hearth is a fairly good conductor at the working temperature, and the loss through a depth of 12 in., which is an ample thickness for a furnace hearth, involves a drop of only 2 volts or 3 volts at a current density of 3 amperes per square inch. The two-phase current is readily obtained from a three-phase supply by the usual plan of Scott-connecting two transformers, or by employing two phases of the four-phase system (to be described later) with two phases cut out and the transformer ratios modified to give two quadrature currents.

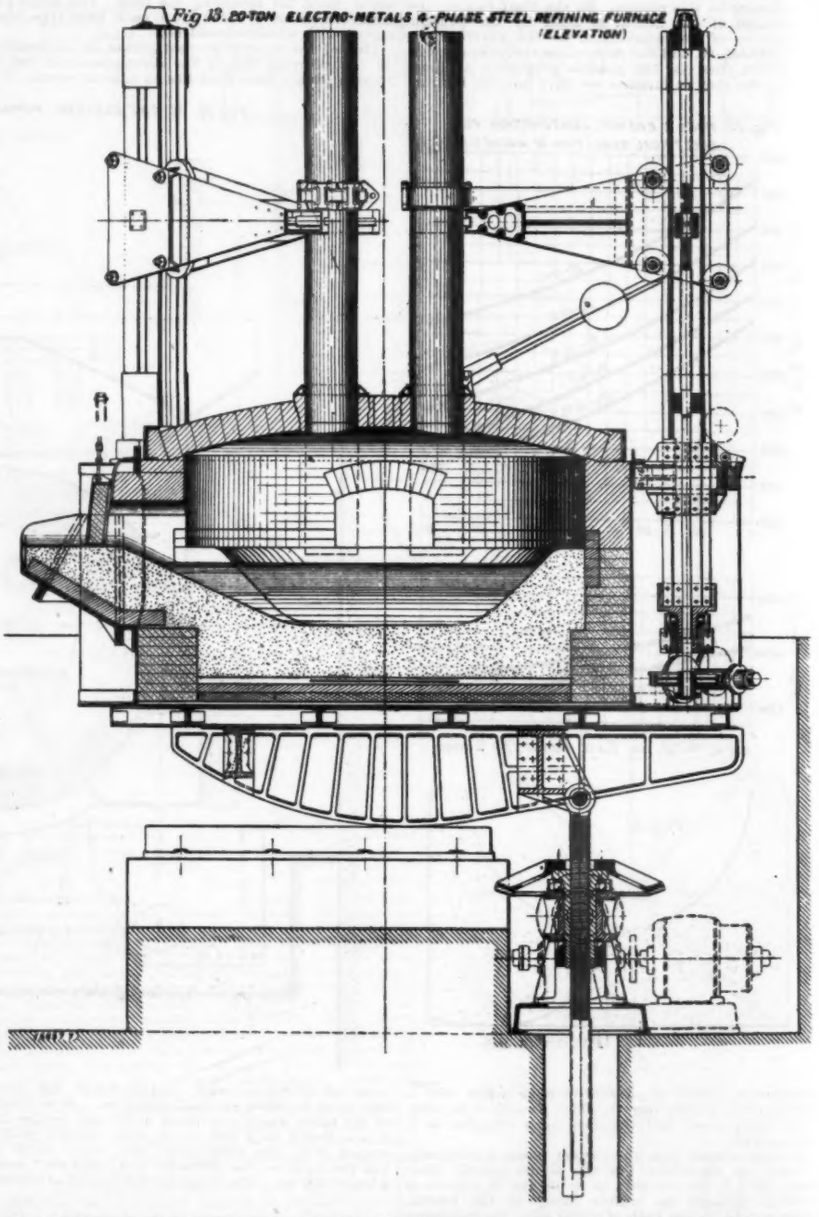
The main field for these small two-arc electric furnaces is in small foundries manufacturing better-quality castings, such as motor-car parts, &c. The castings made from the electric furnace are superior to those made from small converters, since the metal is thoroughly deoxidised and the sulphur content is reduced to a minimum. The predominating cause of defects in steel castings, apart from moulding errors, is the presence of oxides, and the freedom from oxides in electric furnace metal is a positive step forward; also, owing to the reduction in sulphur, the metal is much more ductile and uniform in composition, so that electric steel castings are freer from contraction tears and are much more easily machined. Waster castings, which figure so largely in ordinary steel foundry work, are reduced to an almost negligible quantity. These small electric furnaces are also rapidly displacing the ordinary crucible furnaces for the manufacture of higher quality steels such as ordinary tool, spring, tungsten, nickel-chrome steels, &c. The electric furnace is able to manufacture accurately to specification all kinds of steel from the cheapest raw material, since the reducing atmosphere permits of the alloy additions being made practically without loss.

There is an important use for the small furnace of about ½-ton capacity, and that is the melting of ferro-manganese for use in conjunction with open-hearth furnaces. When solid ferro-manganese is added to molten steel in the ladle, it is only reluctantly absorbed and at least 30 per cent. of the manganese content is lost by oxidation. Portions of the manganese are liable to remain unabsorbed by the steel, and these form manganese ghost lines in working, and hard places which appear in machining. Ferro-manganese can be melted in the small furnace (Fig. 12) which has been specially designed for this purpose, and in which the manganese loss is not more than 5 per cent. There is therefore a great saving in manganese, which is an expensive metal; in fact the saving soon pays for the cost of the furnace, and the steel product is of higher value. These small furnaces have a capacity of 10 cwt. and will deliver molten ferro-manganese at the rate of 400 lb. per hour. The current consumption is 1,000 kw.-hours per ton of ferro-manganese delivered.

Although there are profitable fields for small furnaces, the principal technical developments will take place in larger furnaces. These furnaces may be used either for the complete process of melting, refining and alloying, or may be run in conjunction with Bessemer or open-hearth furnaces, being used to refine the cruder metal from those furnaces. In this case, advantage is simply taken of a feature of the electric furnace, viz., that which permits of working under a non-oxidising atmosphere at any desired temperature.

As previously mentioned, it is important that the heat supplied should be well distributed over the slag-metal contact area in order to ensure that the chemical reactions take place regularly as required. These larger furnaces, consequently, require a greater number of heating zones, that is, a greater number of arcs. The furnace which will now be described has four upper electrodes, which are sufficient for furnaces up to 30 tons' capacity, and two of this size are about to be started up on the Continent. This furnace is shown in elevation and plan in Figs. 13 and 14. The furnace is circular in plan, and the masts which support the electrode carriages are distributed round the furnace as shown. In the scheme of an electric furnace it is

Fig. 13. 20-TON ELECTRO-METALS 4-PHASE STEEL REFINING FURNACE (ELEVATION)



important to have as few openings as possible, and, at the same time, to have these so placed that every portion of the hearth can be surveyed and be accessible for any necessary lining repairs between the heats. Three doors are sufficient, one for teeming and two for charging, but this number is only sufficient if the doors are correctly placed and providing there are no obstructions to the men working at the doors. It will be seen that the disposition of the masts is such that all the mechanism is well clear of the doorways. The motors, which are the mechanisms nearest to the doors, are below the working platform. The doors must be designed to be always free to move and to form a good seal when closed.

The electric system on the large furnace requires, for the reasons given, four equal phases, preferably with only one variable resistance in each phase to facilitate definite regulation. We therefore require four phases with a common return through the hearth

so that the resistance in each phase is equal to the varying resistance of one arc plus the constant resistance of the hearth. The arrangement, as used for a three-phase supply, will now be described. The four-phase five-wire system must be so arranged that the current through the hearth will be a minimum, and this can be taken as the current in one phase, so that when starting the furnace one full arc can be struck independently of the other three upper electrodes.

The system consists of three single-phase transformers, arranged as in Fig. 15, with the primaries delta connected, and the secondaries in such a manner that, from the terminals of two transformers, Y, W, S and R, connections are made to the upper electrodes 1, 2, 3 and 4 respectively; and from the centre M of the third, or teaser secondary to the neutral electrode, N beneath the hearth. From the terminals V and T of the teaser, connections are made to intermediate points X and Z respectively on the other two or main transformers. When arcs are struck beneath the electrodes we have four practically independent circuits. The development of the system is shown clearly in the vector diagram. In Fig. 16 the three circles have radii corresponding to the transformation ratios of the sections of the secondaries to the corresponding primaries. If we consider the three primary windings to be equal, then the radius of the inner circle can represent the number of turns in the sections X W and Z S, the intermediate circle the turns in M V and M T, and the outer circle the turns in X Y and Z R. The vectors E_{ab}, E_{bc} and E_{ca} represent the directions of the voltages across the respective primary windings. The voltage induced between No. 1 electrode and the neutral is equal to the vector sum of the voltages induced in M V and X Y; so that if we mark off along the directions E_{bc} and E_{ab}, distances E_{MV} and E_{XY} corresponding to the turns in M V and X Y, the resultant E_1 will represent the voltage in the No. 1 electrode phase. Similarly, the voltages in the other phases are represented by the vectors E_2, E_3 and E_4. It is a simple matter to proportion the windings so that these voltages are all equal, but it is necessary when equal currents are taken through each of the electrodes, as is the case in normal working, that three equal currents be taken from the primary mains. That this is so will be seen from the current diagram (Fig. 17).

Neglecting induction, the currents in the electrodes can be assumed to be in the direction of the respective voltages, so that we re-draw the voltage vectors obtained in the previous diagram and assume equal currents in the electrodes. The winding W Y is under the influence of the currents in Nos. 1 and 2 electrodes. No. 1 electrode influences X Y turns, and No. 2 electrode influences X W turns, so that if we mark off, along their respective directions, distances corresponding to the turns, for example, I_{XY} and I_{XW}, and then take the vector difference, I_{ab}, this will represent the ampere-turns in W Y, and therefore in the primary $a\,b$. Similarly, the ampere-turns in $c\,a$ are represented by the line I_{ca}. Concerning the winding T V, the current in M V is equal to the vector sum of the currents in electrodes Nos. 1 and 2, and the current in M T is equal to the sum of the currents in Nos. 3 and 4, so that if we mark off along E_1 and E_2 the intermediate circle distance, that is the turns in M V, and then take the resultant I_{MV}, this will represent the ampere-turns in M V. Similarly, I_{MT} represents the ampere-turns in M T, and the vector difference I_{bc} is the ampere-turns across T V, and therefore in the primary $b\,c$. As we assumed the primary turns to be equal, the lines I_{ab}, I_{bc} and I_{ca} will represent the currents in the primary windings, and the sides of the equilateral triangle constructed thereon, I_1, I_2 and I_3, are the currents in the primary wires. The system is therefore balanced for current and pressure under normal conditions of correct regulation.

An electric furnace is, however, inevitably and frequently subjected to abnormal conditions, and it is of importance to know what is happening to the current in the mains when the furnace is working under the worst conditions. As far as the electrodes are concerned, the worst condition is when one arc breaks, as is so often the case. We will therefore assume, for example, that No. 3 phase is broken as in Fig. 18. In the vector diagram, Fig. 19, we have the directions of the currents in the three remaining electrodes, as before, and we will assume that the three currents in these electrodes are equal. The winding W Y is, as before, governed by the currents in Nos. 1 and 2 electrodes, and the ampere-turns across W Y are represented by I_{ab}. The winding S R has only the current of No. 4 electrode, and its ampere-turns are therefore represented by I_{ca}. For the teaser winding we have, as before, I_{MV} and I_{MT}; the difference I_{bc} will represent the ampere-turns in $b\,c$, so that we have the currents in the three primary lines represented by the sides of the triangle I_1, I_2 and I_3. The primary system is not balanced under this condition, but it is quite tolerable. Another extreme case is when one of the transformers has, for some reason, to be disconnected, as shown in Fig. 20. The currents in the primaries under this condition are represented by the three vectors I_1, I_2 and I_3, in Fig. 21, and it will be allowed that this is satisfactory.

It has been previously mentioned that practically all energy dissipated in the hearth is so much loss, and it is therefore important not only to reduce the voltage drop to a minimum, but also the neutral current. If we take this four-phase system, the current through the hearth is the vector sum of the currents in four electrodes, and this is approximately equal to that in one of them. This means that the volume of current through the hearth is, say, one-quarter the arithmetical sum of that in the whole of the electrodes. In the small two-arc furnace the current density is about 3 amperes per square inch; but on the four-phase furnace it is only 1 ampere per square inch, so that the drop in voltage is less than 1 volt, and the loss of energy in the hearth with this system does not exceed 0·3 per cent., and we have an arrangement which gives four independent phases, permitting of good electrode regulation. Careful tests have been made on a transformer group connected up on this system, as shown in Fig. 22. The electrodes were regulated so as to give as nearly as possible the same current, and then spot readings were taken on the ammeters on the primary side. The figures given in the diagram are percentages of the normal, and it will be noticed that the variations from the normal are less than 1 per cent. and the current in the neutral is 5 per cent. greater than that in the electrodes.

An interesting point in connection with arc furnaces is now the subject of an investigation, viz., the nature of an arc load. As is well known, the resistance of an arc decreases with an increase in current, so that with an alternating impressed voltage the specific resistance is at a minimum at the crest of the wave and at a maximum at the zero line. The resistance curve, therefore, has a full pulsation for each half-wave of the fundamental current, and is at a maximum at 90 deg. from the maximum of the fundamental. This can be represented as follows:—

If R is the resistance for the R.M.S. value of the current, and K the factor connecting the amplitudes of the two curves, then:

$$\begin{aligned} r &= R\,(1 + K \sin (90 - 2\,\omega\,t)) \\ &= R\,(1 + K \cos 2\,\omega\,t) \\ &= \frac{e}{r} = \frac{E \sin \omega\,t}{R\,(1 + K \cos 2\,\omega\,t)} \\ &= \frac{E}{2\,R\,(1 - K)}\,[(2 - K) \sin \omega\,t - K \sin 3\,\omega\,t]. \end{aligned}$$

Both second and third harmonics occur, but if we develop the third, for example, in a Scott-connected group, we find that the harmonics are out of phase with two of the fundamentals, which is due to the fact that in such a group two of the third harmonics are the resultants of two third harmonics displaced by three right angles, which brings one resultant third harmonic 120 deg. out of phase with the fundamental. In the development of any transformer system for arc loads

Fig. 14. 20-TON ELECTRO-METALS 4-PHASE STEEL REFINING FURNACE (PLAN)

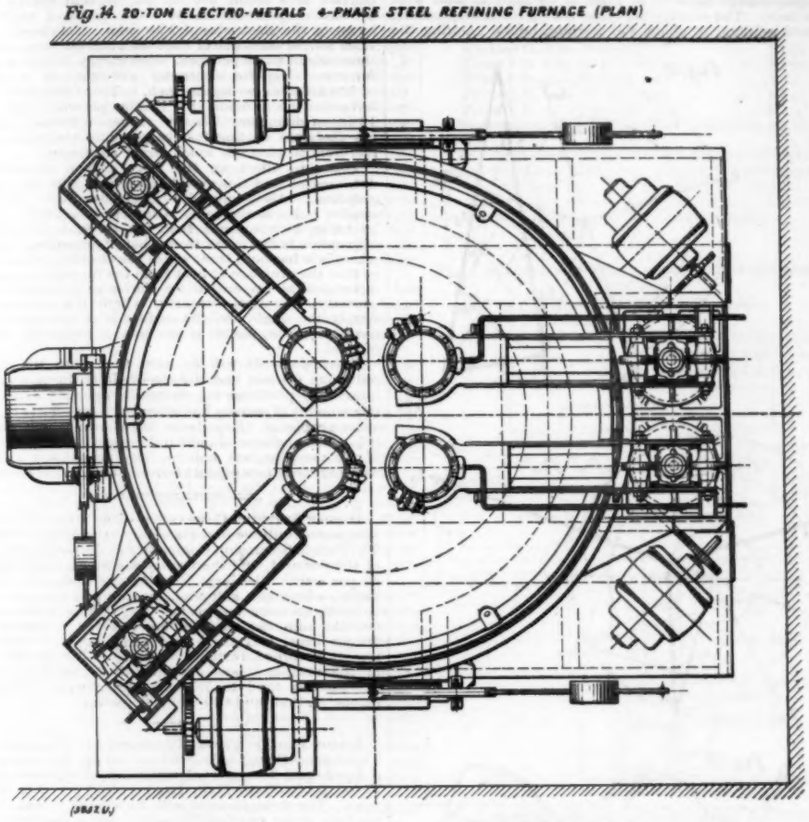


Fig. 15.

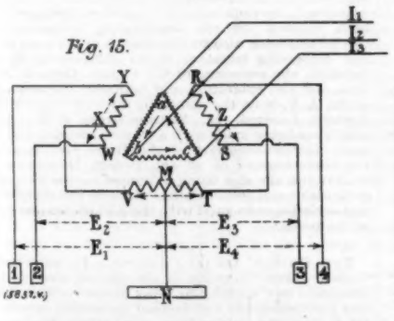


Fig. 16. VOLTAGE DIAGRAM

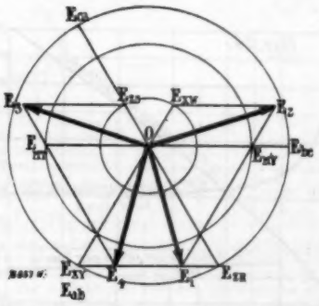
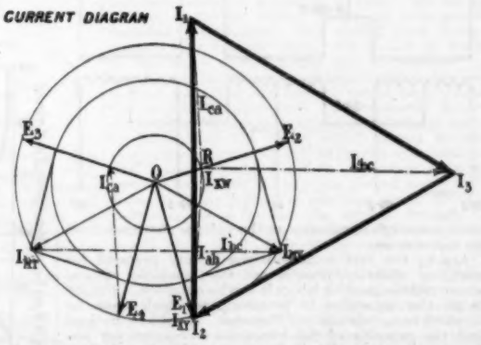


Fig. 17. CURRENT DIAGRAM



the effect of the third harmonic must be taken into account, as it is necessary that the third harmonics in the primary should be as nearly as possible in phase with the fundamentals at the maximum, so that the curves will not be too unsymmetrical. In the four-phase system we have third harmonics in the four secondaries, and it is a simple matter to develop the harmonics back on to the primary lines and see that they are almost in phase with the primary fundamentals. The distortion of the primary voltage waves is negligible Dr. Chapman has analysed one of these current waves on a Scott group (Fig. 23) and finds it can be represented by the following equation :—

$$i = 2{\cdot}34 \sin\theta + 0{\cdot}202 \sin 2\theta + 0{\cdot}168 \sin 3\theta + 0{\cdot}566 \cos\theta - 0{\cdot}43 \cos 2\theta - 0{\cdot}17 \cos 3\theta.$$

This oscillogram shows the voltage-current relationship, and indicates a power factor of about 0·8. The small twenty-seventh harmonics on the voltage curve are from the transformer.

Among the first considerations in any proposal for installing electric furnaces are the available electric power and the price at which it can be obtained. Fig. 24 shows the capacities of transformers which must be supplied for given sizes of furnaces. It will be noticed that the capacity of the transformer required per ton decreases as the size of the furnace increases. This is because the radiation losses are proportionally greater in the smaller furnaces. Also, as is indicated on the same diagram, the consumption of current per ton decreases as the size of furnace increases. On a well-designed furnace the power factor is in the neighbourhood of 0·8, but it is necessary to have a large reactance, say, 10 per cent. or 12 per cent., in the system to choke the unavoidable fluctuations of current in the arc. From the electrical standpoint the most severe trial to which the plant can be put is when it is required to melt rough cold scrap, and when working on this duty momentary overloads of from 50 per cent. to 70 per cent. may occur, so that the transformers must be designed for such an emergency. The load factor on a single furnace working night and day is about 35 per cent., but when working two furnaces it is 50 per cent., which compares favourably with other loads on electric generating stations. It is unlikely that there will be much decrease in the consumption of current in the steel furnace of the future, since the thermal efficiency of a modern plant is about 65 per cent. Improvements will rather tend toward mechanical reliability and more durable refractories, especially for the roof. The metal will be melted in large plants by Bessemer or open-hearth processes and then charged into electric furnaces for refining and alloying. The electric furnace is not a cheap melter, its value being in its refining properties. When hot crude metal is charged into the electric furnace the energy and time required for refining is about one-third of that required for melting and refining, so that a furnace charged with hot metal has three times the capacity of one charged with cold stock.

With respect to refractories, the electric furnace is practically always lined with a basic hearth, which shows it up to greater advantage in desulphurising. The hearth is built in exactly the same way as in an ordinary open-hearth furnace, so there is no need to deal with it here. The average life of the roof is 100 heats, melting and refining, or about 400 working hours. During the war, when the cost of refractories was abnormally high, it was found that the average total refractories including periodic relining, amounted to less than 8*s.* per ton of metal melted and refined.

Electrodes.—One of the most important items in the cost of running an electric furnace is that of electrodes, not only because of their initial cost, but also because of the time lost in renewing them. In the reduction furnace the electrodes are embedded in the loose material. They are not regulated as in the steel furnace, but are simply pushed down every two or three days as they burn away. Now on a 4,000-h.p. furnace, with electrodes 28 in. in diameter embedded, say, 6 in., the area exposed to the material is about 1,000 sq. in. When passing 20,000 amperes the drop between an electrode and the material is about 20 volts, that is, the contact resistance is equal to 0·001 ohm. Since, in the reduction furnace, it is desirable to have as great a voltage drop between the electrodes as possible, in order to get sufficient energy into the furnace, and as the distance between them cannot be increased conveniently, the only way to increase the voltage is to increase the drop between the electrode and the material ; and to do this we must decrease the contact surface, that is, the size of the electrode. In the reduction furnace we are therefore confronted with the problem of requiring an electrode which has a greater conductivity than the carbon electrodes now being used, so as to reduce the contact surface. With carbon electrodes, when working at 40 amperes per square inch on the large 28-in. size, we have a voltage drop at each electrode of 20 volts, and about 40 volts in the resistance of the intermediate material, giving a total drop of 80 volts. If we had an electrode which would work at 120 amperes per square inch, the diameters would only be about 16 in., and the contact area about 500 sq. in., so that the electrode contact drop would be 40 volts, giving a total drop between the electrodes of 120 volts. This would mean that, for the same size of electrodes and the same current, there would be 50 per cent. more energy delivered to the furnace. Graphite electrodes will work at a density of 120 amperes per square inch, but, unfortunately, they have not been made, up to the present, more than 12 in. in diameter. Electric reduction furnace builders are therefore waiting for the graphite electrode manufacturers to turn out much larger electrodes.

The skin effect on the large carbon electrodes is detrimental, and this would be reduced with the smaller graphites. Also, graphite electrodes will allow of smaller holes in the roof. On the other hand, it must be taken into account that the thermal conductivity of graphite is five or six times that of amorphous carbon, whereas it has only three times the electric conductivity, so that the drainage of heat from the furnace by graphite is twice that by carbon for the same current-carrying capacity. In steel furnaces, where the resistance is simply the single arc, the surface is of no importance ; the determining factor is the cost of electrodes per ton of steel.

Conclusion.—It will be seen that both the electric reduction furnace and the steel-refining furnace present interesting problems for electrical engineers, and that a fair amount of success has attended their efforts to solve these problems. Experience has shown how important it is that engineers should fully grasp the requirements of the metallurgists, and be fully acquainted with the working conditions of blast furnaces and of steel foundries.

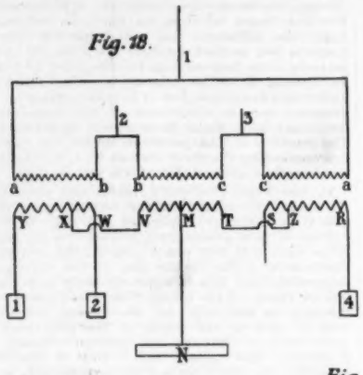


Fig. 18.

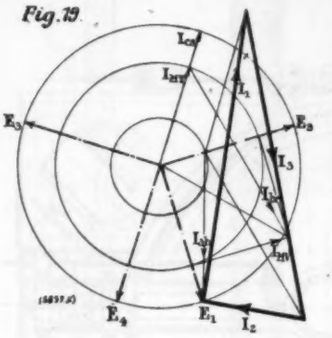


Fig. 19.

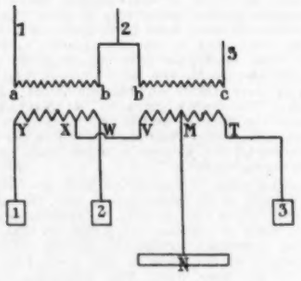


Fig. 20.

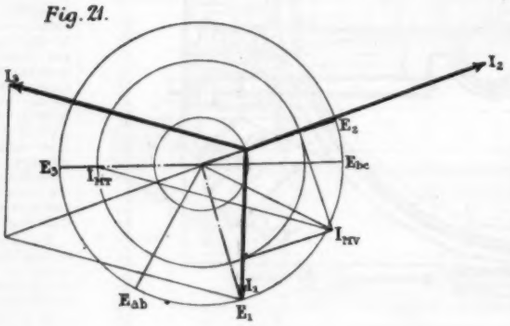


Fig. 21.

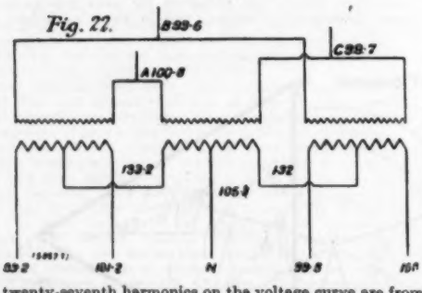


Fig. 22.

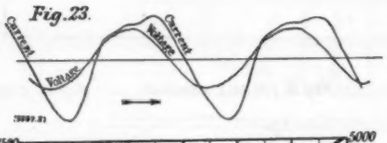


Fig. 23.

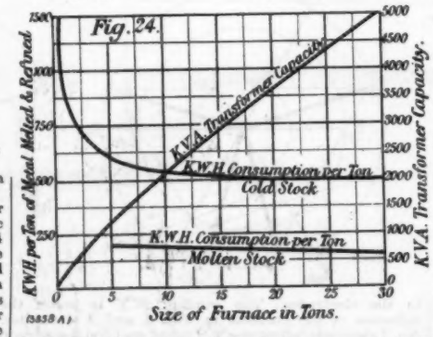


Fig. 24.

Fig. 19.

Danish Shipping Companies.—The Danish steamship companies continue to declare very substantial dividends. The Pacific Steamship Company has declared a dividend of 100 per cent, and the Dannebrog Steamship Company 50 per cent. The large East Asiatic Company, Copenhagen, which is a shipping, trading and manufacturing concern, earned a surplus last year of 39,872,099 kronen. Of this sum the shareholders received a dividend of 30 per cent. and taxes and contribution to the coal import absorbed 14,868,433 kronen. The reserve fund of the company now amounts to 50,000,000 kronen, the pension fund to 7,000,000 kronen and a kind of reconstruction fund to 1,500,000 kronen.

Roads and Transport Congress and Exhibition.—The County Councils Association has decided to organise a Roads and Transport Congress and Exhibition at the Royal Agricultural Hall, London, in November of this year. The arrangements will, to a large extent, follow the lines of the successful Roads Congress and Exhibition organised by the Association in 1915, but, in view of the important developments in regard to transport, it has been decided, on the forthcoming occasion, to pay special attention also to this branch of the road problem. The organising secretary of the Congress is Mr. S. M. Johnson, the secretary of the County Councils Association, and the exhibition will be under the management of Mr. A. F. May, the managing director of the Municipal Agency, Limited, 13, Victoria-street, S.W. Arrangements are being made with a view to securing the attendance of representatives of the Home Government and the Governments of all the British Dominions, while invitations are also being extended to the various local authorities and to all professional and commercial bodies and societies connected with the administration and user of the roads.

The United Alkali Company.—In addressing the United Alkali Company in the annual meeting held at Liverpool last month, Mr. Max Muspratt said that they had just before the war decided on making arrangements for a complete change from the Leblanc process to the electrolytic process, because the ammonia-soda process, which they had adopted, did not yield chlorine. There had, however, been delay, and that had proved of incalculable benefit for the country, because they had been able to place their sulphuric acid at the disposal of the explosive works. They had also made picric acid, by Professor Green's process, and had supplied one of the ingredients for amatol and that further sodium hyposulphite (for the first gas masks used), and had been instrumental in the supply of six lethal gases, four of which had proved extremely effective. Other products of theirs had been superphosphate, calcium chloride (for the volt storage industry) and sulphur dyes. The company now employed some 10,000 workers ; they had an experienced staff and had spent £2,500,000 on extension of plant. Yet the general outlook was unfavourable owing to the serious position of the foreign trade and general unrest, and Government control, which had operated unfairly in their own case, should be removed. After making the fullest allowance for the exigencies of the war, Mr. Muspratt could not but say that the unnecessary interference caused by Government control had cost the country untold millions.

A NEW TYPE OF ELECTRIC FURNACE.*

By AXEL SAHLIN.

Introduction.—The electric furnaces hitherto constructed may be divided into three different groups, viz. :—

(*a*) Induction furnaces ;
(*b*) Furnaces with a free-burning arc ; and
(*c*) Furnaces relying on a direct arc between the metal and the bath.

The first-mentioned type of furnace is now only occasionally found.

The free-burning arc furnaces have found favour, especially for work where it is desirable to avoid any chemical reaction between the carbon in the electrodes and the bath. They have a decided advantage in giving the means of heating the cold furnaces without the introduction of any charge and by the arc only.

On the other hand, they have the disadvantage that, as soon as the bath is formed, the heat is transmitted to the surface only and no circulation is set up in the molten metal.

Many furnaces of this type have suffered from defective and weak mechanical construction. On that ground some users have preferred direct arc furnaces, in spite of the disadvantages of heavy and cumbersome electrodes, furnace roofs pierced by large holes, and the necessity of using a source of heat other than the electric current to bring the furnace up to melting temperature.

The furnace which is the subject of this paper has been designed with a view to embodying the advantages of both the direct arc and the free-burning arc furnaces, at the same time avoiding as far as possible the disadvantages of both.

Description.—The furnace is built as a circular ladle with contracted top and dished bottom. The shell is made of heavy steel plates, riveted together with ¾-in. rivets closely spaced. The plates are perforated by ½-in. drilled holes, spaced about 12 in. apart and serving as vents for moisture contained in the lining. The top rim is reinforced by a heavy flat hoop riveted to the shell plates. The steel casting trunnions are riveted to the shell and rest in bearings set so as to allow for expansion and alignment. To the overhanging end of one trunnion is keyed a crank which, by means of an enclosed screw, running in oil, working in a swivelled crosshead and turned by hand wheel (or, for larger furnaces, by motor), serves to tilt the furnace to any desired angle.

The bottom of the furnace is made up of a layer of coke dust and tar rammed in, supporting double layers of brick. On top of this is rammed and fixed in successive layers a hearth consisting of burnt dolomite and tar for basic operation, or of ganister in case the acid process is adopted. Supported and resting on the firebrick, outside the hearth, is placed a circular lining backed by a heavy insulating layer of asbestos sheet and formed of circle-bricks laid with ground joints and thin mortar. This lining may be made of magnesite brick for basic process, or of silica brick for acid process. In the lining are placed on the same vertical lines two holes for each pair of electrodes, and one door opening which serves both to charge the furnace and to pour the steel. For larger furnaces one tapping hole and two charging doors would be a better arrangement.

On top of the contracted top of the side lining rests the dome-shaped roof built of basic or acid brick fitted in a circular steel frame, forming a rigid skewback. The roof joint is made of a layer of powdered dolomite or ganister spread on top of the side wall. The roof can be removed by crane without delay, and replaced by another preheated roof held in readiness to take its place. As it is found that the portion of the roof opposite to the arcs is affected more readily than the portion nearest to the electrodes (which is protected to a certain extent by the shadow of the latter) the roof can be turned round to any angle desired. Thus, when the weakest portion is getting thin, the life of the roof can be prolonged by exposing to the fiercest heat the section of the roof hitherto more protected.

It is also possible to charge the furnace through the top by removing the roof while the charge is put in place.

Electrodes.—The electrodes are graphite or carbon electrodes, of cylindrical form, extended as they are burnt away by screwing a new section of electrode to the rear end of the electrode in operation. The joint is made by threaded dowels of graphite. The electrodes slide through water-cooled electrode holders made of steel pipes welded to rings at the front and back ends. Nozzles for water supply and discharge are tapped into these rings, and are connected with rubber hose to the water mains. The electrodes are wrapped in sheets of asbestos, mica, or fibre, and are thus insulated from the furnace body.

The electrode cooler with its insulation is placed between the fixed upper and sliding lower jaws of a clamp which is pivoted to a frame bolted to the furnace shell. A wedge placed beneath the lower jaw of the clamp causes it to grip and firmly hold the insulated cooler with the electrode sliding through the same.

The top part of the clamp is extended outward, forming a support and U-shaped guide for the slide which grips the rear portion of the electrode. In the hollow interior of the U-shaped guide works a screw which engages against a nut held in place by prongs extending from the electrode holder. If the screw is turned, the electrode holder is moved toward or away from the furnace, advancing or retiring the electrode.

* Paper read at a joint meeting of the Institution of Electrical Engineers and the Iron and Steel Institute on Thursday, May 8, 1919.

The upper portion of the electrode holder is insulated from the grip by a sheet of fibre. The lower swivelling portion of the grip is closed and tightened by an eye bolt with hand wheel nut. Both halves of the grips are water-cooled, and are fed through nipples connected to the water mains by rubber hose. Both grips are made with an extending wing, to which is bolted the bronze cable socket which receives the end of the cables, transmitting the current from the switchboard to the electrode. Both the swivelled guides are adjusted in a vertical sense, controlling at will the inclination of the electrode.

Electric Arrangement and Wiring.—The number of electrodes proposed is as follows :—

For a furnace hearth—

Up to 3 ft. 6 in. diameter ...	...	1 pair.
From 3 ft. 6 in. to 5 ft. diameter	...	2 pairs.
From 5 ft. to 7 ft. diameter ...	...	3 ,,
From 7 ft. to 9 ft. diameter ...	...	4 ,,
From 9 ft. to 11 ft. diameter ...	...	6 ,,

This number can be modified according to circumstances.

The electrodes should be preferably of graphite, varying from 2 in. up to 6 in. diameter, according to the size of furnace and the amount of current. Each pair of electrodes enters the furnace in the same vertical plane, but at different and adjustable angles.

Fig. 1. DIAGRAM OF WIRING OF A TWO-PAIR SAHLIN FURNACE.

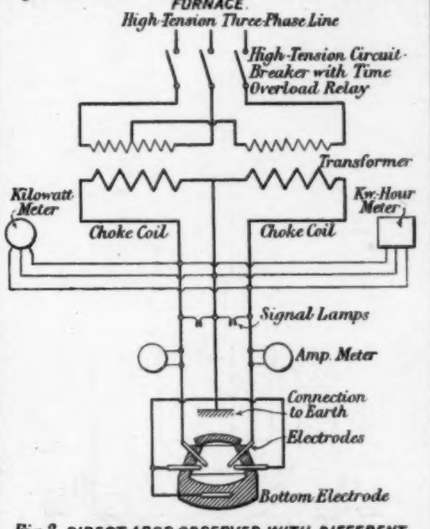


Fig. 2. DIRECT ARCS OBSERVED WITH DIFFERENT POSITIONS OF ELECTRODES.

The upper electrodes are supplied with current. The lower electrodes, as well as the furnace body (and, if the furnace is going to be used largely for refining work, a bottom electrode bedded in the hearth) are connected with the common of the transformer, or earthed.

For a one-pair furnace, direct current or one-phase alternating current is used.

For a two-pair furnace it is preferable to employ two-phase current, generally obtained by three-phase transformers arranged in Scott's coupling.

For a three-pair furnace, three-phase current is used, one phase being coupled to each upper electrode.

For furnaces with more than three pairs of electrodes, groups of two pairs are coupled in parallel ; therefore, a four-pair electrode furnace uses two-phase current, whereas a six-pair furnace should be supplied with three-phase current. If for any reason it may be found desirable, the upper electrodes can be earthed, and the current can be supplied through the lower electrodes. A bottom electrode bedded in the hearth may be used or not. It is useful when refining because, as the lining material gets very hot, it becomes a good conductor and passes the current through the bath into the bottom electrode when using the direct arc.

The pressure of the supply should preferably be transformed to 100 volts which, by plugs on the transformer, may be reduced at option to 80 volts or 70 volts.

The connections for a two-pair furnace are shown in Fig. 1. To avoid any chance of shock to operators, it is advisable to place a wooden operating platform over the floor at the back of the furnace around the electrodes. All the electrodes are distributed around the half of the circumference of the furnace opposite to the tapping hole and charging doors. For the smaller sizes of furnaces, the electrodes are fed forward by hand wheels.

The current taken is observed by reading kilowatt meters placed on a switchboard suitably located, and receiving the feeders from the transformers. It seems to me an advantage to provide choke coils to steady the current.

Operation.—Assuming that the furnace is to be used for melting and refining steel, the first operation is the heating of the furnace to the proper temperature. This is effected by turning on current and gradually advancing the points of the convergent electrodes of each pair until an arc is formed. Experiments have proved that as long as the points of the electrodes are at a certain distance from each other an arc is formed between the two electrodes. As the electrodes approach each other this arc bends outward, forming a loop. If the distance is still further reduced, the loop breaks and the arc rushes forward, sweeping downward toward the surface of the metal like a broom. If the top electrode is advanced beyond the bottom electrode, the broom is deflected downward (see Fig. 2). The form and direction of the arc can easily be modified by altering the angles of the electrodes and their relative position to each other. The free-burning arc heats the furnace while empty.

The second operation would be the charging. When the furnace is heated, current is taken off, and the electrodes are drawn toward the back wall of the furnace to prevent their being injured, while the material to be melted is thrown or pushed into the furnace through the charging door, or eventually through the furnace top, the roof having been removed. As soon as the charge has been placed in the furnace, the electrodes are advanced. Experience has shown that numerous momentary arcs are formed between the upper electrodes and the charge, but as this latter is melted away in the vicinity of the electrodes, the regular free-burning "broom" arc is formed between the two electrodes and the working of the furnace settles down to normal. The radiation and reflection caused by the free-burning arc are most effective for rapid melting. As, however, the bath is formed, this kind of arc reaches only the slag-covered surface of the metal, causing but little circulation in the interior of the bath. At this point, therefore, the free-burning arcs are broken by the retirement of the lower electrodes and a direct arc is formed by the advancing of the upper inclined electrodes toward the surface of the slag. If the bottom electrode is employed, the current will penetrate toward this bottom electrode which is earthed. The furnace is now working on the lines of a Girod furnace, and creates an electric arc which causes a rapid circulation in the bath and direct transfer of heat to the metal.

In furnaces with more than one pair of electrodes, it is possible to have some of the electrodes produce a direct, and some a free-burning arc, thus making use of the effective radiating and reflecting action of the free-burning arc, at the same time as the bath is agitated by the direct arcs.

Special Work.—For use as a heating furnace for very high temperatures such as are required for the production of graphite, for the calcining of magnesite, for the crystallising of bauxite, for special crucible work, and for other similar objects, it is proposed to suspend the furnace shell containing the side walls and roof with the electrodes and the electrode mechanism from four lifting rods, operated by electric motor, hydraulic cylinder, or windlass. The bottom of the furnace which for this work does not require any bottom electrode would be placed on a truck. On this portable bottom would be placed, in proper arrangement, the material to be heated. The loaded truck being placed beneath the furnace body, this would be lowered on to the truck enclosing the pile of material. A free-burning arc would now be started between the electrodes in each pair, and the furnace would be brought up to the required temperature. The material having been thoroughly heated or calcined, the furnace body would be lifted from the truck, which would be run away to give place to a second truck loaded with fresh material. The loaded trucks could be preheated in a gas-fired furnace before the bottom was placed under the electric furnace. This procedure has been described only as an indication of a use for the electric furnace, filling a long-felt want, but the actual arrangement of the plant would, no doubt, be different for each case and should be separately studied.

Advantages.—It will be found that the furnace, as above described, is of a very strong construction—rigid, simple and durable. All the surfaces of the brick linings are convex, and the walls will therefore be held in position. The surface of the melting room, confined by spherical and cylindrical walls, is the smallest possible for the largest volume, and the amount of brickwork in the furnace is therefore reduced to a minimum. The electrodes are easily secured in place, adjusted, advanced, or retracted by means of hand wheels. There are no bolts or nuts manipulated by wrenches used in the adjustment of the furnace, every operation being carried out by hand wheels or cotters. The roof is solid, without any openings, removable and exchangeable in a minimum space of time. The furnace can be run either with free-burning arcs, with direct arcs, or with free-burning and direct arcs working simultaneously side by side. Changes are made without cutting off the current.

When the furnace is employed as a free-burning arc furnace no chemical reaction between carbon of the electrodes and the bath takes place. The overhanging length of the electrodes is comparatively short, and the arcs are formed fairly close to the circular furnace walls, being directed inward and downward toward the centre of the furnace.

The Sahlin furnace has not yet been placed on the market owing to the difficulty of obtaining a permit for its construction during the war, but a furnace is now being built in Great Britain intended for the production of steel ingots and castings.

THE BOOTH-HALL ELECTRIC FURNACE.*

By W. K. BOOTH.

THE principal difference between the various makes of electric furnaces is the method in which the power is introduced in the furnace. The general metallurgical operations of practically all electric arc furnaces are the same. The method of power regulation and bringing the power to the furnace frequently means greater or less cost in furnace operation and governs, to a considerable extent, the manner in which the furnace lining may be put in and consequently the refractory cost and the loss of time due to furnace shut-downs.

Electric arc furnaces may be broadly divided into two classes :—

(1) Vertical arc furnaces.
  (a) Conducting hearth.
  (b) Non-conducting hearth.
(2) Horizontal arc furnaces.

It is not the purpose, here, to enter into a discussion of the merits of the various types of arc furnaces, but more particularly to describe a new type of electric furnace which has been developed during the last year and which is known as the Booth-Hall electric furnace.

The Booth-Hall electric furnace comes under class 1 (a) above, and is illustrated diagrammatically in Figs. 1 to 4.

Fig. 1 is a longitudinal section of the two-phase electric furnace while Fig. 3 shows the auxiliary electrode resting upon the charge and arcs drawn between the main electrodes and the charge. A pool of metal is shown forming on the hearth of the furnace.

BOOTH-HALL TWO-PHASE FURNACE.

Fig. 1

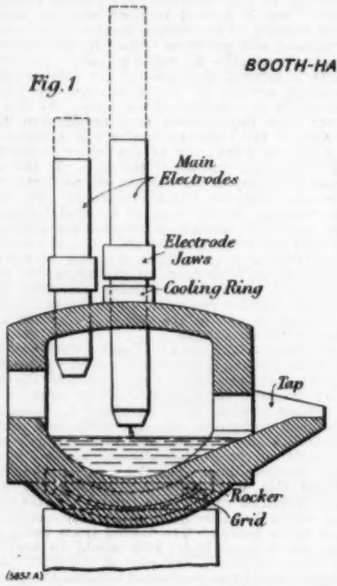


Fig. 2.

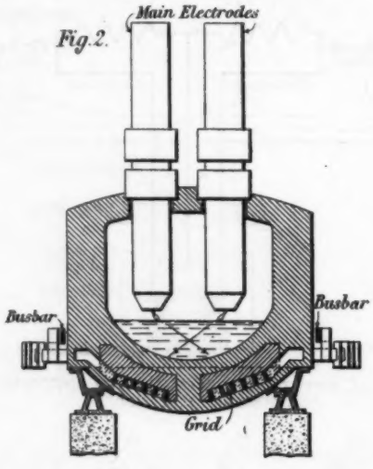


Fig. 3. ELECTRICAL CONNECTIONS OF BOOTH-HALL TWO-PHASE FURNACE.

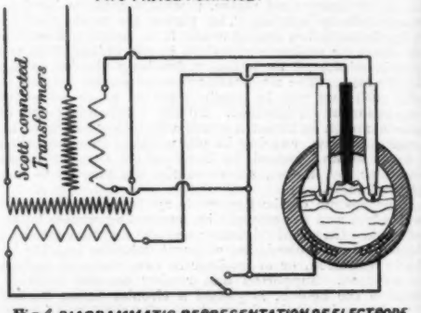


Fig. 4. DIAGRAMMATIC REPRESENTATION OF ELECTRODE ARRANGEMENT.

Fig. 2 is a diagram of a transverse section of the two-phase electric furnace, showing the crossing action of the current in the bath and the grids embedded in the hearth.

Fig. 3 is a diagrammatic representation of the electrical connections for the two-phase electric furnace employing two single-phase Scott-connected transformers. This diagram shows the connections from the transformer terminals to the main electrodes and to the auxiliary electrode and grids. A two-phase electric furnace so connected gives a balanced load on a three-phase power service. The auxiliary electrode is shown in black.

Fig. 4 shows diagrammatically the arrangement of main and auxiliary electrodes in single, two, and three-phase Booth-Hall furnaces. The auxiliary electrodes are shown in black.

The furnace is built either single, two, or three-phase to suit the conditions at the place of installation, the general principle being a furnace having a solid hearth which becomes conductive of electricity when hot, and the use of an auxiliary electrode which acts as a return for the electric current until the hearth becomes heated and conductive.

In starting furnace operation on a cold charge the auxiliary electrode is lowered until it rests on top of the charge, and the arc is then drawn between the charge and the main electrodes or electrode, as the case may be, the auxiliary acting as a return for the main electrode or electrodes. The auxiliary is so arranged that it presses with its entire weight on top of the charge and consequently no arc can form underneath the auxiliary ; experience has demonstrated that no arc does form. The auxiliary is connected in parallel with the conducting hearth, and when the main electrodes or electrode have melted enough metal to form a pool on the bottom the hearth becomes conductive and the auxiliary is withdrawn from contact with the charge. In a cold furnace the auxiliary is in operation from 30 minutes to 45 minutes, and, in a furnace which is hot, less than 15 minutes ; that is, only long enough to assure a positive start of the furnace and a balanced load on the power company's line.

Furnaces from ½ ton to 6 tons' holding capacity are generally built for two-phase operation, taking power from three-phase service by means of Scott-connected transformers, as shown diagrammatically in Fig. 3. In the hearth of the Booth-Hall two-phase electric furnace two sets of grids are embedded, which are electrically insulated from each other and are so related to the main electrodes that the current of the two phases cross in the bath, thus giving a maximum of circulation of the molten metal and causing, in conjunction with the effect of the bottom heating, a very thorough mixing of the metal in the bath. This action can readily be observed on looking into the furnace after the charge has entirely melted. The conducting grids are placed as far as possible from the heated interior of the furnace, and experience has shown that they never become overheated or require special cooling. The grids are so constructed as to handle large currents, furnishing large areas of contact with the material of the conducting bottom, and preventing local heating due to contact resistance.

By the use of the auxiliary electrode a positive start of the furnace is guaranteed, and there is no possibility of failure to secure contact. Each main electrode is dependent of the other, as there are no arcs in series and consequently the regulation of the furnace is very simple, giving a balanced polyphase load on the power service lines. As with the two-phase connection there are only two electrodes to regulate, this offers the minimum number of electrodes for a balanced polyphase load, and the smaller the number of electrodes requiring regulation the smoother becomes the furnace operation.

The hearth is either acid or basic, as desired, and in each case is at least 24 in. (60 cm.) in thickness, being sintered in place layer by layer and forming a monolithic mass. By using the main electrodes in conjunction with the auxiliary, the materials of the hearth are sintered together in thin layers similar to open-hearth practice, thus forming a very durable bottom and making the danger of run-outs a minimum. The furnace hearth is consequently solid, with no water cooling of any kind. With the basic hearth, dead burned dolomite is used to maintain the slag line ; in the acid furnace, ground ganister is used for the same purpose. The conducting hearth gives a uniform bottom heating of the entire bath, prevents sculls, and makes speedier and more thorough distribution of the heavier alloys, which tend to sink to the bottom of the bath. The effect of this bottom heating is considerable, and has been accurately measured on Booth-Hall furnaces in continuous operation.

With the two-phase electric furnace a minimum of electrode consumption is secured, due to the fact that a minimum number of electrodes for a balanced polyphase load is used. This means fewer electrodes to handle, less electrode breakage, and less surface burning. The loss on the auxiliary electrode is small, because it is in operation for such a comparatively short time. The electrode jaws are made so that the electrodes can be gripped or released by turning a hand wheel or lever at the side of the furnace, and it is not therefore necessary for the melter to climb on top of his furnace when changing the grip on the electrodes. The electrode jaws are arranged in segments so as to take up and adjust themselves to the inaccuracies in the surface of the electrodes.

A roomy charging door of special construction is provided in the rear of the furnace, and another door in front over the tap. This construction is very similar to the open hearth, and permits a battery of furnaces to be arranged side by side and a charging machine to serve them all. The furnace tilts or rocks backward as well as forward, and slagging operations can be handled from either the rear or the front as desired. The door is shown in the photographs exhibited. It is designed so that it comes flush against the door frame, sealing the opening, and cannot swing open of its own accord. This prevents air getting into the furnace and also prevents excessive losses of heat through the door. The door can be opened anywhere from a few inches to full open when inspecting the bath, taking tests, or pushing scrap from the sides of the furnace into the bath, thus protecting the melter from the heat of the furnace and preventing great radiation loss. Any warping of the door or frame does not affect the operation of the door or its sealing of the opening when closed.

The furnace is motor tilted, in all sizes, for pouring, but is arranged so that it can be tilted by hand in emergency if the motor fails to operate. The smaller sizes of furnace are built for hand operation only, if desired. All parts of the tilting mechanism, including gears and motors, are arranged so that they do not come beneath the furnace, and therefore there is nothing under the furnace that can be injured in case of a run-out.

The main electrodes are arranged for automatic regulation and also, in every case, so that they can be regulated by hand in case the regulators or motors should require repair.

The importance of power control is universally recognised, especially when refining operations are carried on. In the Booth-Hall electric furnace the power input can be maintained at any point from one-fourth to full load by means of proper voltage reduction and control switches.

In making steel for the ordinary grade of steel castings, the Booth-Hall electric furnace has operated with a power consumption as low as 446 kw.-hours per 2,000 lb. (906 kg.) of steel poured, but the average will be between 500 kw.-hours and 550 kw.-hours per net ton for continuous operation. In one of the 4-ton furnaces a considerable quantity of low phosphorus pig-iron has been made, running over 0·035 per cent. in phosphorus and sulphur, also special steels requiring refining with two or more slags, the power consumption, of course, depending upon the degree of refining required.

* Paper read at a joint meeting of the Institution of Electrical Engineers and the Iron and Steel Institute, on Thursday, May 8, 1919.

HOUSING SCHEME, SYDNEY HARBOUR TRUST.—We read in the Sydney Harbour Trust Commissioners' eighteenth report, for the year ending June 30, 1918, that shortly after the outbreak of the war the employees of the Trust formed an association, the object of which was "To build homes for the widows of soldiers and disabled soldiers who were employed by the Sydney Harbour Trust Commissioners at the time of enlisting." Since its formation the members of the association have been most assiduous in their work, and have given up much of their spare time in forwarding the good object in view. The association is financed by the voluntary contributions of 6*d.* per week by the employees, augmented by some contributions from the Commissioners and office staff. The total contributions from May 6, 1916, to date, amounted to 1,531*l.* The first work undertaken was the erection of four cottages at French's Forest, including the fencing in of the 5-acre blocks and the clearing of over 2 acres of land in each allotment. The expenditure on these cottages by the association was 550*l.* They have since erected three cottages in Tramway-street, Tempe, at a cost to them of 368*l.*, and renovated a cottage in Botany-street, Randwick, at a cost of 141*l.* Another cottage in Tramway-street, Tempe, is now in course of erection. The cottages at Tempe are mortgaged for 300*l.* each, being the cost of the material only, and arrangements have been made by which, with the assistance of the State Government, the occupiers may become owners in fifteen years by the payment of the small sum of 5*s.* 9*d.* per week.